Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-83

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4 April 1997

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FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center Photo/Video Analysis, reports from Johnson Space Center and Marshall Space Flight Center are also included in this document to provide an integrated assessment of the mission.

Photo 1: Launch of Shuttle Mission STS-83

1.0 SUMMARY

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 3 April 1997. The detailed walkdown of Pad 39A and MLP-3 also included the primary flight elements OV-102 Columbia (22nd flight), ET-84 (LWT 77), and BI-086 SRB's. There were no significant vehicle or launch pad anomalies.

The launch, originally scheduled for April 3rd, was delayed 24 hours while insulation was added to a payload chilled water line.

The Final Inspection of the cryoloaded vehicle was performed on 4 April 1997 from 0915 to 1040 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No Ice, Debris, or TPS IPR's were taken. Due to the mid-afternoon launch time and warm weather conditions, there were no acreage icing concerns. There were also no protuberance icing conditions outside of the established data base.

After the 2:20 p.m. (local) launch on 4 April 1997, a debris walk down of Pad 39A was performed. No flight hardware or TPS materials were found. All the T-0 umbilicals operated properly. Overall, damage to the launch pad was minimal.

A total of 109 films and videos were analyzed as part of the post mission data review. No vehicle damage or lost flight hardware was observed that would have affected the mission. With the exception of Mach diamond formation (in the order 3-1-2), SSME ignition appeared normal. A stud hang-up occurred on HDP #7. A shaved piece of aluminum from the bore wall fell past the HDP shoe shortly after T-0. No stud hang-ups or frangible nut/ordnance debris was observed on any of the other holddown posts with the exception of a small fragment near the HDP #5 DCS. Thermal curtain tape on the right SRB near HDP #4 came loose at T-0.

OV-102 was equipped to carry ET/ORB umbilical cameras. Four TPS divots were visible in the intertank-to-LH2 tank flange closeout in the -Y+Z quadrant outboard of the -Y bipod housing. The divots spanned the entire width of the closeout (9-11 inch diameters), but were not deep enough to show shadow or primed substrate. Three more TPS divots were detected in the intertank-to-LH2 tank flange closeout between the bipods. Two of the divots were located close to centerline /+Z axis while the third divot appeared to be in the general area of the -Y bipod standoff closeout. These three divots were approximately 6-7 inches in diameter and shallow.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums were in excellent condition. No TPS was missing and no debonds were detected over fasteners or acreage. All eight BSM aero heat shield covers appeared to be locked in the fully opened position, though all four cover attach rings on the right frustum had been bent by parachute riser entanglement. The upper right cover was missing. Signs of a stud hang-up were evident on the HDP #7 foot with broaching of the bore wall. Stud thread impressions were also present in the wall. The holddown post Debris Containment Systems (DCS) plungers were seated and appeared to have functioned normally with the exception of #5, where the plunger was obstructed by the frangible nut halves. This condition may have been the result of splashdown.

Orbiter performance as viewed on landing films and videos during final approach, touchdown, and rollout was nominal. Drag chute operation was also normal.

A post landing inspection of OV-102 Columbia was conducted 8 April 1997 at the Kennedy Space Center on SLF runway 33. The Orbiter TPS sustained a total of 81 hits, of which 13 had a major dimension of 1-inch or larger. A comparison of these numbers to statistics from 67 previous missions of similar configuration indicates both the total number of hits and the number of hits 1-inch or larger were less than average.

The Orbiter lower surface sustained a total of 38 hits, of which 7 had a major dimension of 1-inch or larger. The largest lower surface tile damage site was located on the body flap. The site measured 2-inches long by 1-inch wide by 0.125-inch maximum depth. The damage was probably caused by an impact from ET/ORB umbilical ice.

Bent metal, approximately 1-inch in length by 1/4-inch wide, was visible on the trailing edge of a spacer between two bolt heads on the inside surface of the LO2 ET door near the forward outboard corner. This same condition has occurred after the last three flights on different Orbiters.

Hazing and streaking of forward-facing Orbiter windows was typical. Damage sites on the window perimeter tiles appeared to be greater than usual in quantity and size. Two damage sites greater than 1-inch in size within a cluster of 11 hits were present in the black tile area between windows #3 and #4. These damage sites are believed to be the result of impacts from excessive RTV adhesive used in attaching paper covers to the FRCS thrusters.

2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 3 April 1997 at 1230 hours. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Tatum	NASA - KSC Chief, ET/SRB Mechanical Systems
G. Katnik	NASA - KSC Shuttle Ice/Debris Systems
J. Lin	NASA - KSC Shuttle Ice/Debris Systems
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M. Bassignani	NASA - KSC ET Mechanisms/Structures
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R. Page	NASA - KSC Level II Integration
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R. Seale	USA - SPC ET Mechanical Systems
J. Blue	USA - SPC ET Mechanical Systems
W. Richards	USA - SPC ET Mechanical Systems
M. Wollam	USA - SPC ET Mechanical Systems
G. Fales	USA - SPC ET Mechanical Systems
F. Foster	BNA - LSS Systems Integration
B. St. Aubin	THIO - LSS SRM Processing
S. Otto	LMSO - LSS ET Processing
J. Ramirez	LMSO - LSS ET Processing
M. Barber	USA - Safety

3.0 LAUNCH

STS-83 was launched at 97:094:19:20:32.019 UTC (2:20 p.m. local) on 4 April 1997.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 3 April 1997. The detailed walkdown of Pad 39A and MLP-3 also included the primary flight elements OV-102 Columbia (22 flight), ET-84 (LWT 77), and BI-086 SRB's. There were no significant vehicle or launch pad anomalies.

The launch was delayed 24 hours while insulation was added to a payload chilled water line.

3.2 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 4 April 1997 from 0915 to 1040 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No Ice, Debris, or TPS IPR's were taken. Due to the mid-afternoon launch time and warm weather conditions, there were no acreage icing concerns. There were also no protuberance icing conditions outside of the established data base.

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain vehicle surface temperature measurements for an overall thermal assessment of the vehicle, particularly those areas not visible from remote fixed scanners, and to scan for unusual temperature gradients.

3.2.1 ORBITER

No Orbiter tile or RCC panel anomalies were observed. The F4R, R2R, and L2D RCS thruster covers were intact, but tinted green indicating small internal vapor leaks. Ice/frost and condensate had formed on SSME #1 and #2 heat shield-to-nozzle interfaces. The SSME #3 heat shield was dry. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

3.2.2 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the STI radiometers were close to ambient temperatures. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature supplied by THIO was 71 degrees F, which was within the required range of 44-86 degrees F.

3.2.3 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a comparison to infrared scanner point measurements. The program predicted condensate, but no ice or frost, on the ET acreage TPS.

The Final Inspection Team observed no condensate, ice, or frost accumulations on the LO2 tank. TPS surface temperatures ranged from 52-62 degrees F.

The intertank acreage exhibited no TPS anomalies. Ice/frost accumulation on the GUCP appeared less than usual.

The Final Inspection Team observed no condensate, ice, or frost accumulations on the LH2 tank acreage. TPS surface temperatures averaged 52 degrees F.

Less than usual amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets.

An 10-inch long by ¼-inch wide stress relief crack had formed on the -Y vertical strut forward facing TPS. The presence of the crack was expected and acceptable for flight per the NSTS-08303 criteria.

A hairline crack was detected in the -Y thrust strut-to-tank joint TPS closeout. This condition has been observed on previous launches and was acceptable for flight per the NSTS-08303 criteria.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost accumulations were limited to small patches on the aft and inboard sides. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Ice and frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier outboard sides, but typical on the forward surface. Smaller than usual ice/frost fingers were present on the pyro canister and plate gap purge vents. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

3.2.4 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch.

No leaks were observed on the GUCP or the LO2 and LH2 Orbiter T-0 umbilicals.

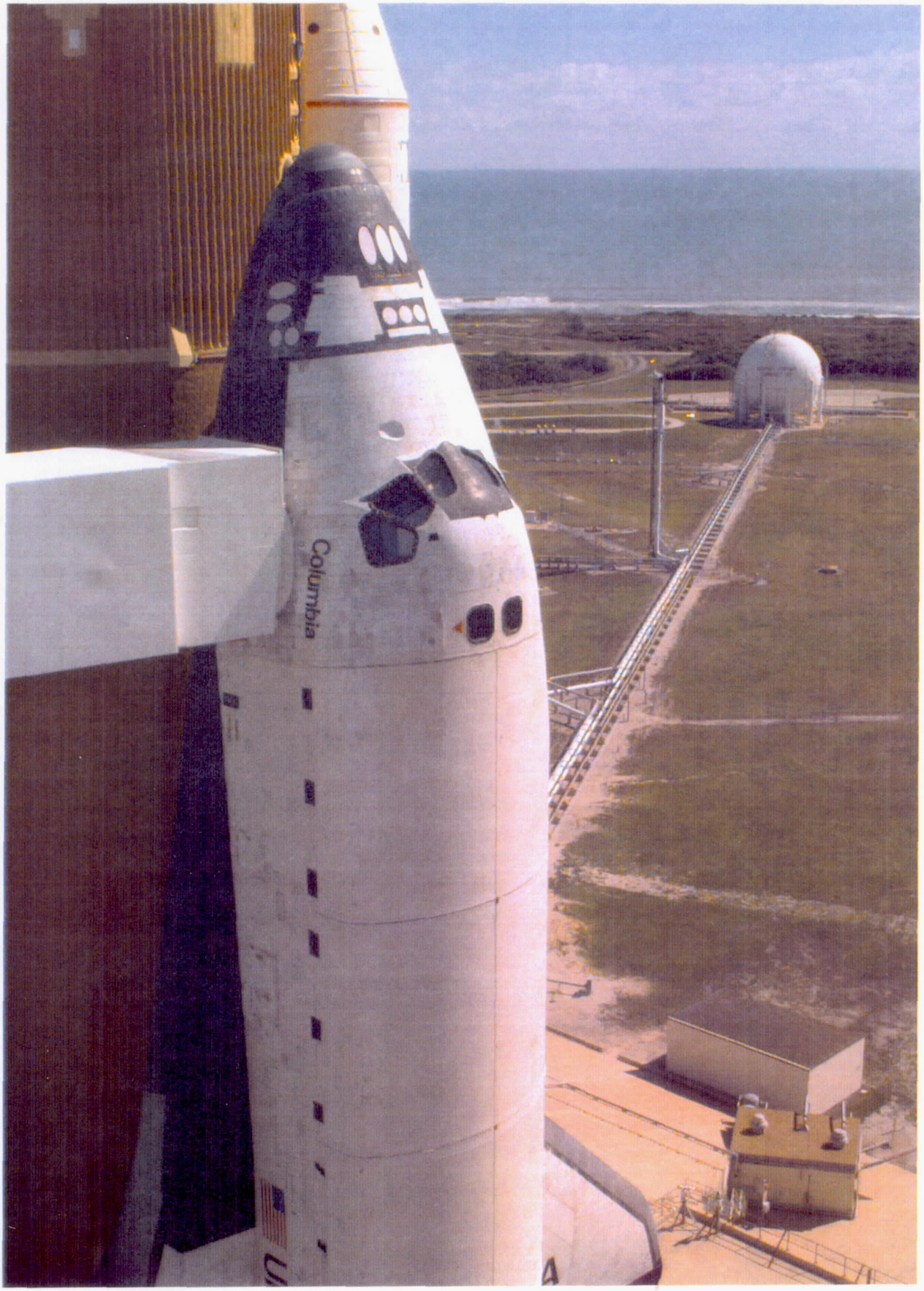


Photo 2: STS-83 Ready for Launch

OV-102 (22nd flight), ET-84 (LWT 77), BI-086 SRB's

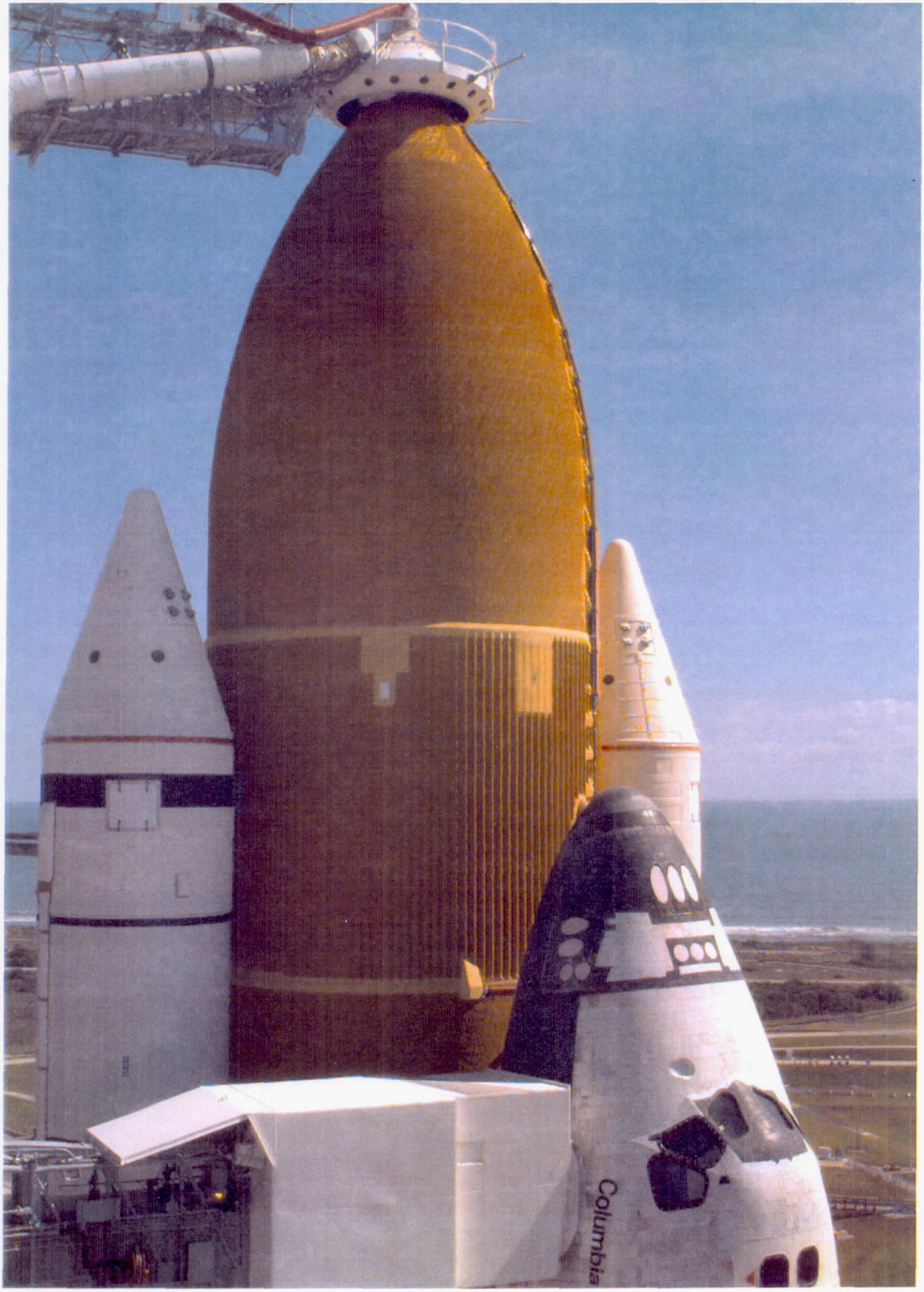


Photo 3: LO2 Tank After Cryoload

The Final Inspection Team observed no condensate, ice, or frost accumulations on the LO2 tank. TPS surface temperatures ranged from 52-62 degrees F.

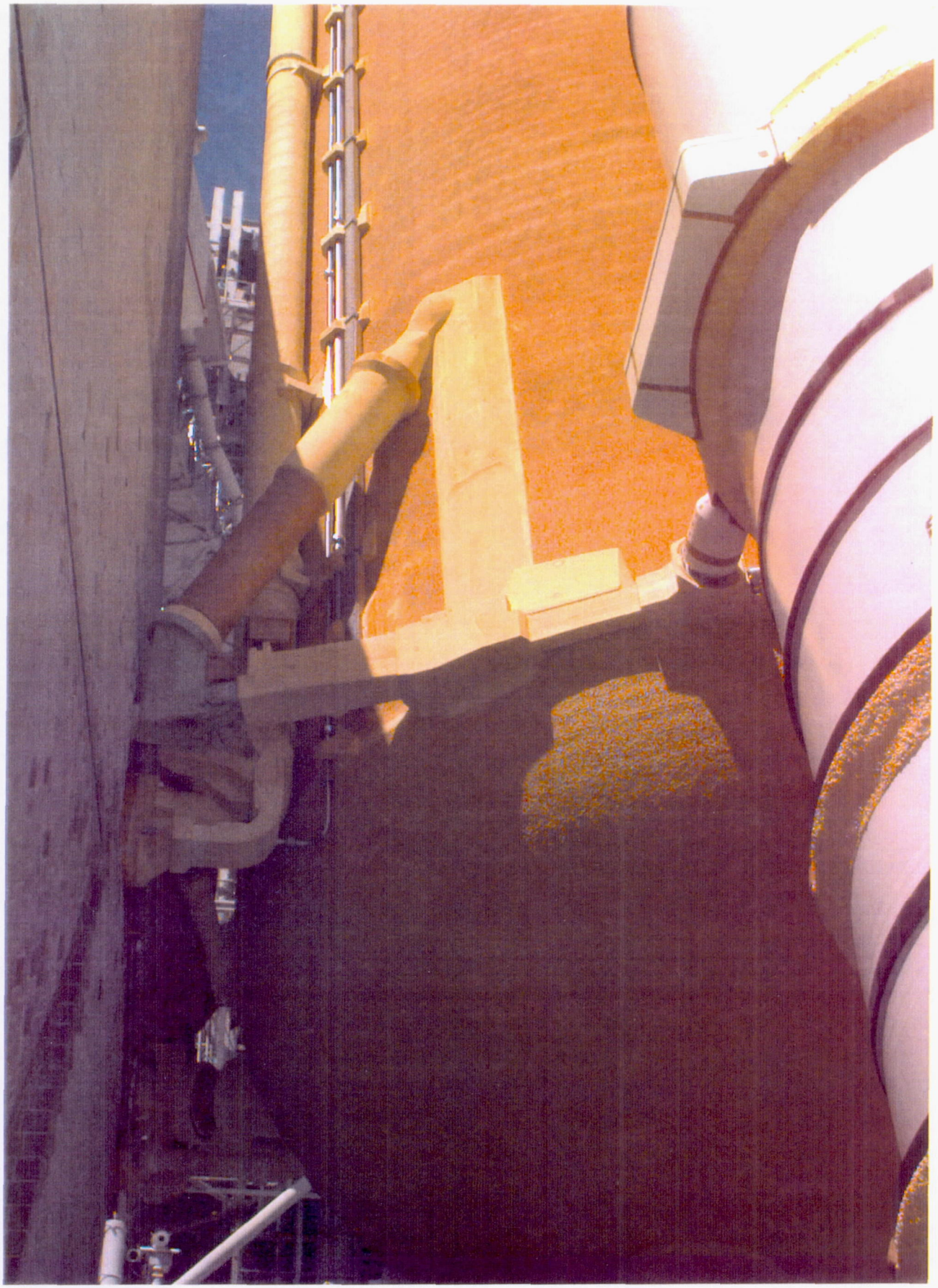


Photo 4: LH2 Tank After Cryoload

The Final Inspection Team observed no condensate, ice, or frost accumulations on the LH2 tank acreage. TPS surface temperatures averaged 52 degrees F.

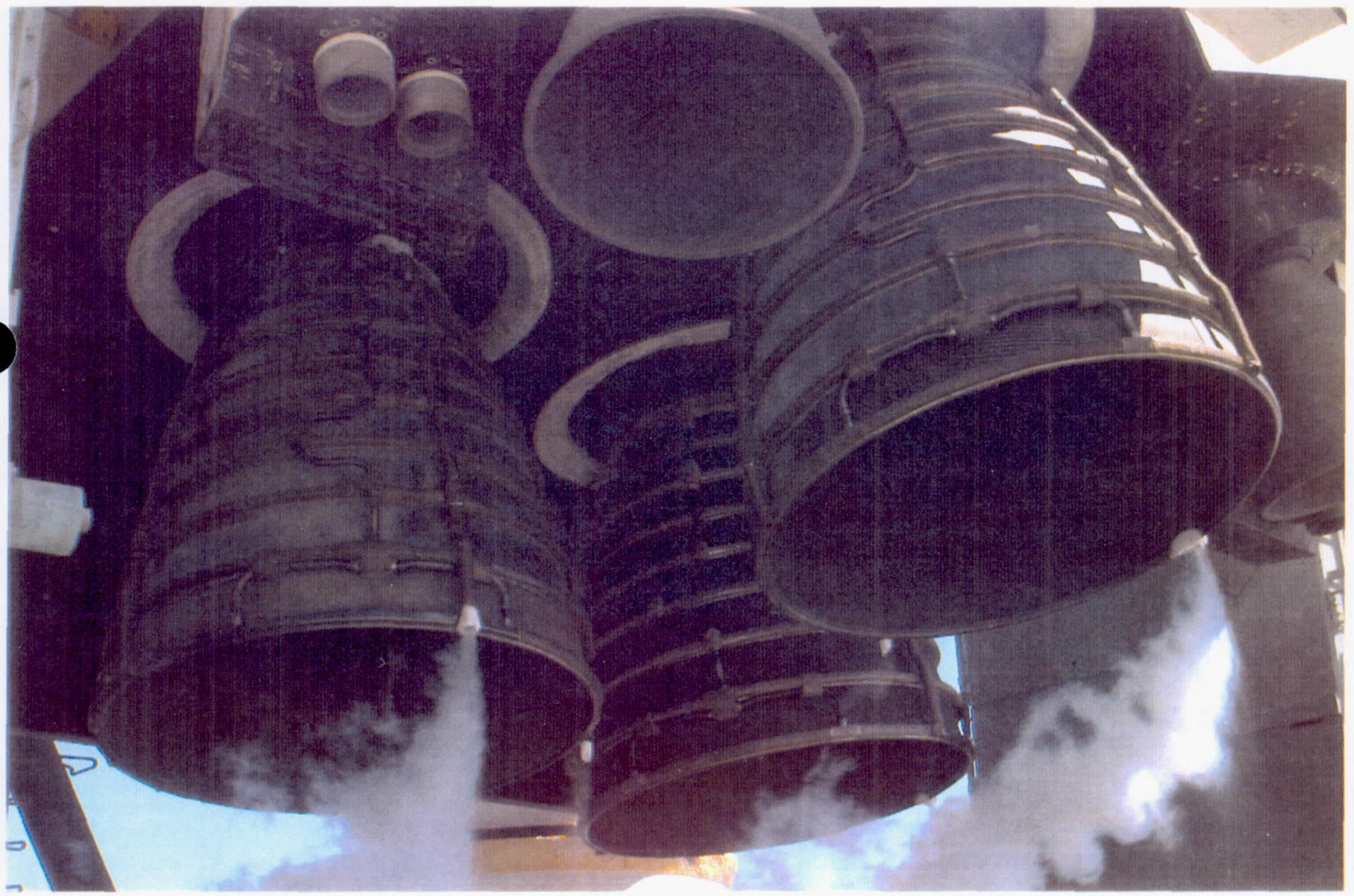


Photo 5: Overall View of SSME's

Photo 6: LH2 ET/ORB Umbilical

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier outboard sides, but typical on the forward surface. Smaller than usual ice/frost fingers were present on the pyro canister and plate gap purge vents.

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of MLP 3, Pad A FSS and RSS was conducted on 4 April 1997 from Launch + 1.5 to 3 hours.

SRB Hold Down Post (HDP) erosion was typical. Boeing North America - Downey reported a lateral acceleration of 0.29 g's, which may be indicative of a stud hangup. Pad inspection showed no sign of a stud hang-up. However, HDP film analysis and more detailed HDP/SRB aft skirt inspections verified the event.

HDP blast covers closed properly. Epon shim material was debonded 12-inches along the forward, outboard edge of HDP #1 shoe, no missing material was noted. The belly band at the base of HDP #4 was damaged (bent outward). Aft skirt purge lines and T-0 umbilicals exhibited typical exhaust plume damage.

The Tail Service Masts (TSM), Orbiter Access Arm and Gox Vent Arm had no visible indications of damage. TSM bonnets were closed. The GOX Vent seals were evaluated from the GVA hood access platform, no damage or residue was noted on the seals.

The GH2 vent line was latched in the sixth of eight teeth of the latching mechanism. The ET GUCP had not been struck by the retract lanyard. The yoke bearing for the retract cables was twisted, with no damage present.

Pad safety reported material loss and damage to the firewall in the south flame trench. Debris team inspection of the north flame trench showed a 2-foot by 8-inch area of missing firewall material from the flame deflector. Pieces of material were found on the pad apron, the mobile launch platform 0-level and the north flame trench.

Miscellaneous facility straps and clamps were found on the pad apron and acreage. The blast deck at the ECS connection tower NW of the MLP had damage. The northeast stadium light set had three broken covers and one broken bulb. A PA speaker horn was damaged at the FSS 135-foot level. An Oxidizer panel operation placard was found on the pad apron.

Overall, damage to the pad appeared minimal.

5.0 FILM REVIEW

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No IPR's or IFA's were generated as a result of the film review.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 87 films and videos, which included thirty 16mm films, twenty 35mm films, and thirty-seven videos, were reviewed starting on launch day.

With the exception of Mach diamond formation (in the order 3-1-2), SSME ignition appeared normal (OTV-051, -070; E-19, -20, -76). Free burning hydrogen drifted up to the OMS pods. A flash in the SSME #2 Mach diamond during start-up may be indicative of a momentary contaminant in the fuel.

Pieces of ice were shaken loose from the LO2 feedline upper bellows (OTV 061). No contact with the lower surface tiles was observed.

SSME ignition caused pieces of ice to fall from the ET/ORB umbilicals. Several pieces of ice contacted the LH2 umbilical cavity sill and were deflected outward. One piece of ice from the LH2 feedline bellows contacted lower surface tiles approximately fifteen feet forward of the body flap hinge. No tile damage was visible (OTV-009).

Loss of tile surface coating material was again noted at the acoustic focal point on the base heat shield between SSME #3 and #1 (OTV 054).

Tile surface coating material was lost during ignition from six places on the base heatshield outboard of SSME #3 (E-17), one place on the -Y side of the SSME #3 heat shield (E-20), one place on the aft surface of the LH RCS stinger (E-20), and two places on the aft surface of the RH RCS stinger (E-17). Surface coating material was also lost from several tiles on the base heat shield between SSME #3 and #1 at the acoustic focal point (E-19).

A thin, 5-inch long by 1-inch wide object appeared from the base heat shield area behind SSME #3 and fell aft at 19:20:29.416 UTC. The object was more flexible than a GSE tile shim and may have been a tile gap filler (E-17).

Three small pieces of debris entered the field of view from above and fell aft at 19:20:30.075 UTC. The debris may have been gap fillers or RTV sealant (E-18).

GUCP disconnect from the ET and GH2 vent line retraction was nominal (E-33, -36).

A stud hang-up occurred on HDP #7. A shaved piece of aluminum from the bore wall fell past the HDP shoe shortly after T-0 (E-11). No stud hang-ups or frangible nut/ordnance debris was observed on any of the other holddown posts with the exception of a small fragment near the HDP #5 DCS (E-12).

Thermal curtain tape on the right SRB near HDP #4 came loose at T-0 (E-1, -5, -7, -15).

A flash occurred in the SSME #1 plume at T+8 seconds MET (E-52).

Most of the ET/ORB umbilical purge barrier material came loose and fell aft at the beginning of the roll maneuver 19:20:49-51 UTC (E-52, -54).

Three debris-induced streaks occurred in the SSME exhaust plume during ascent (E-222, -223).

Light-colored particles, most likely pieces of instafoam from SRB aft skirt aft rings, fell along side the SRB exhaust plume at T + 18 seconds and T + 67 seconds (TV-4A).

Typical body flap movement (amplitude and frequency) was visible in film item E-212.

Exhaust plume recirculation was also typical (E-208).

SRB exhaust plume recirculation appeared typical.

SRB separation appeared normal. Slag fell from the exhaust plumes just before, during, and after separation (E-208, -212, -223).

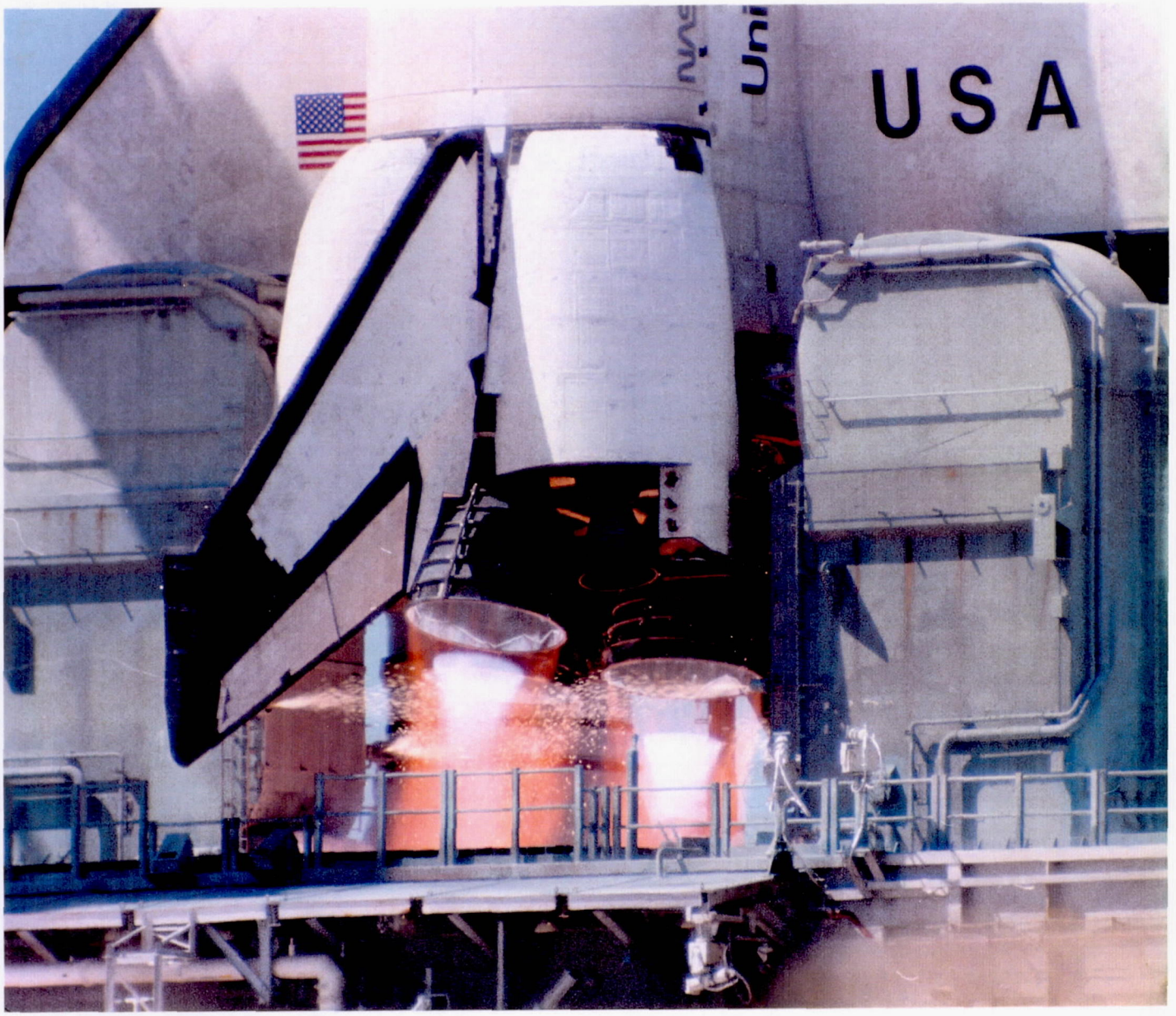


Photo 7: SSME Mach Diamonds Formed in a 3-1-2 Order

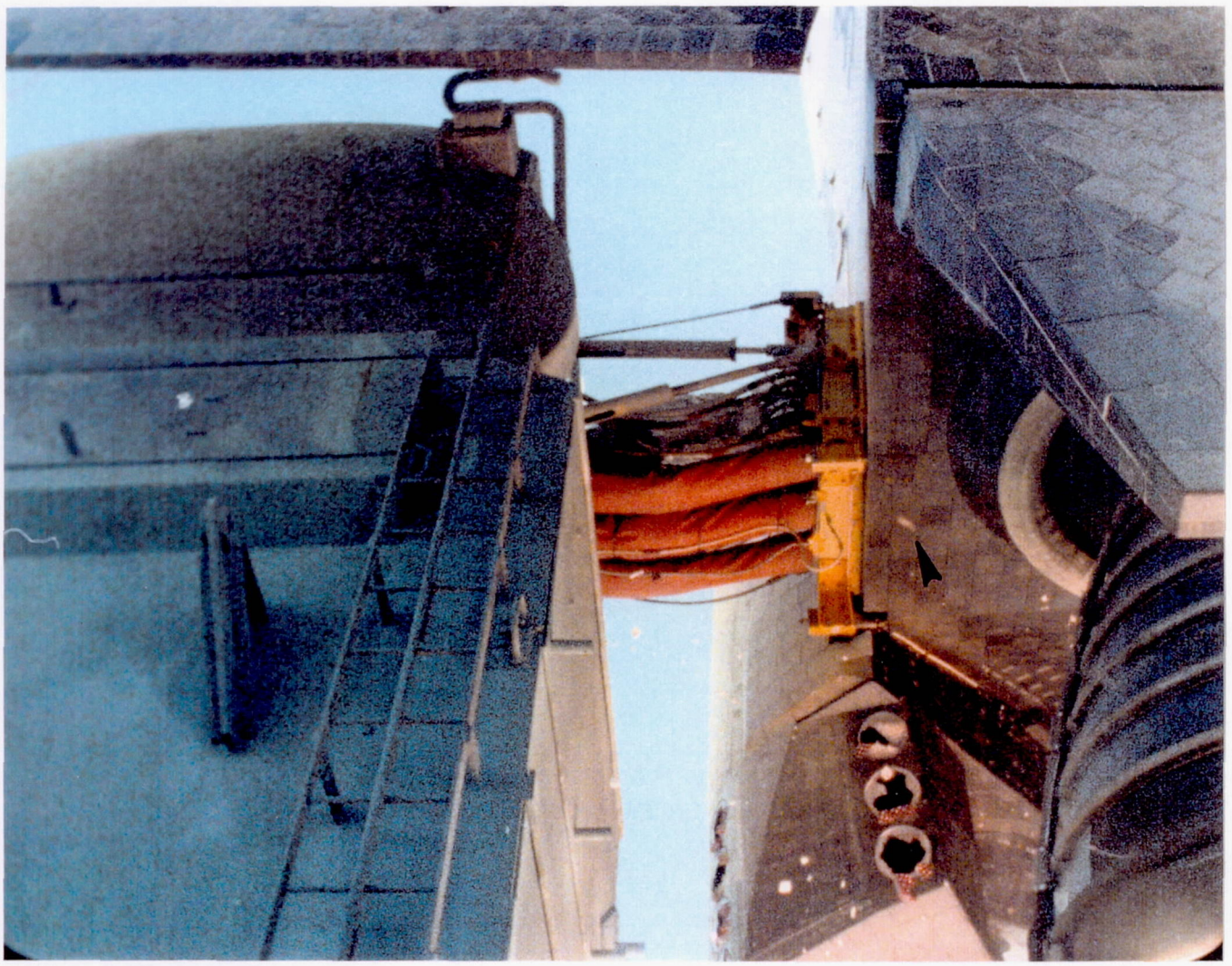


Photo 8: Tile Gap Filler

A thin, 5-inch long by 1-inch wide object appeared from the base heat shield area behind SSME #3 and fell aft at 19:20:29.416 UTC. The object was more flexible than a GSE tile shim and may have been a tile gap filler.

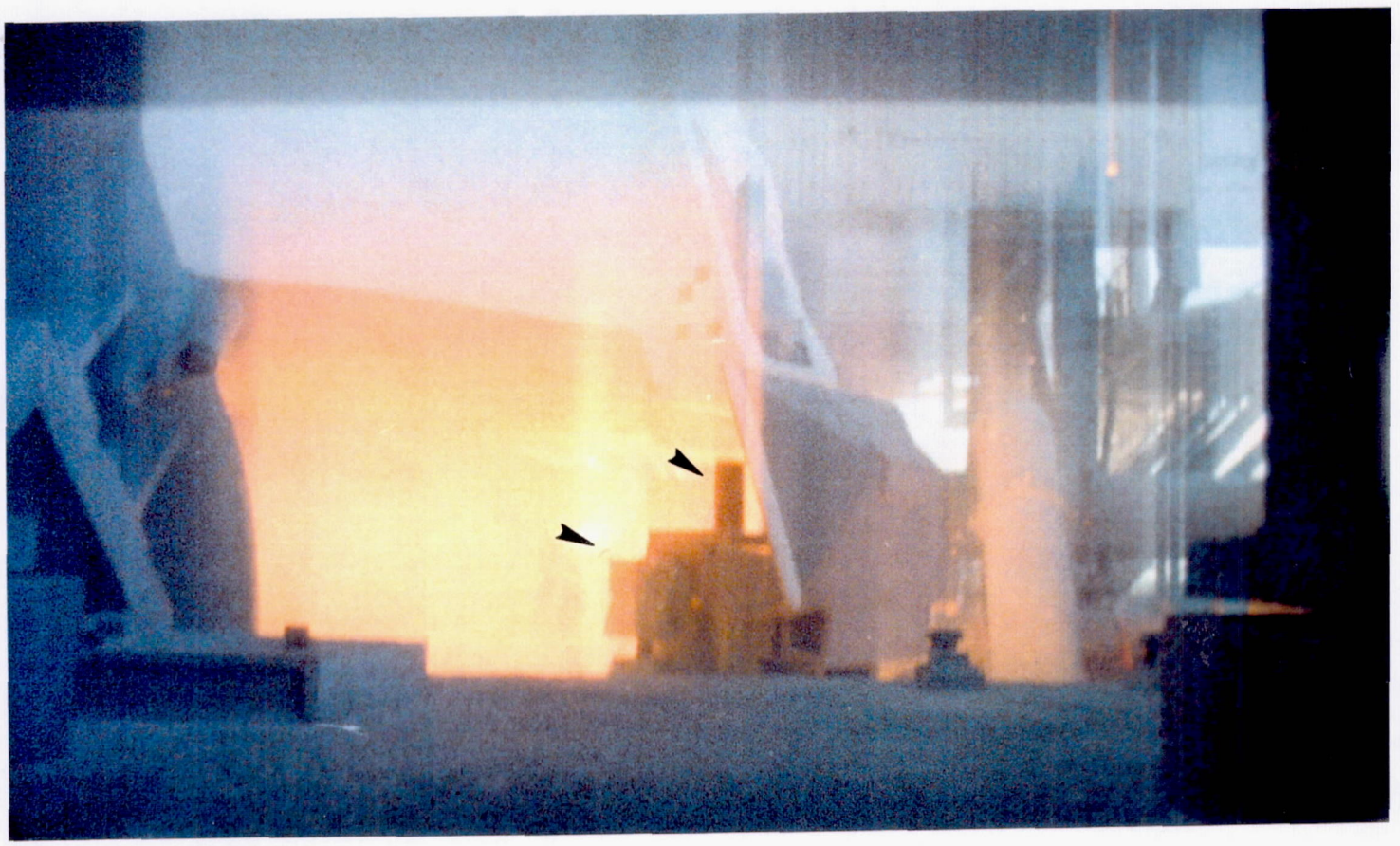


Photo 9: HDP #7 Stud Hang-Up

A stud hang-up occurred on HDP #7. A shaved piece of aluminum from the bore wall fell past the HDP shoe shortly after T-0. No stud hang-ups or frangible nut/ordnance debris was observed on any of the other holddown posts with the exception of a small fragment near the HDP #5 DCS.

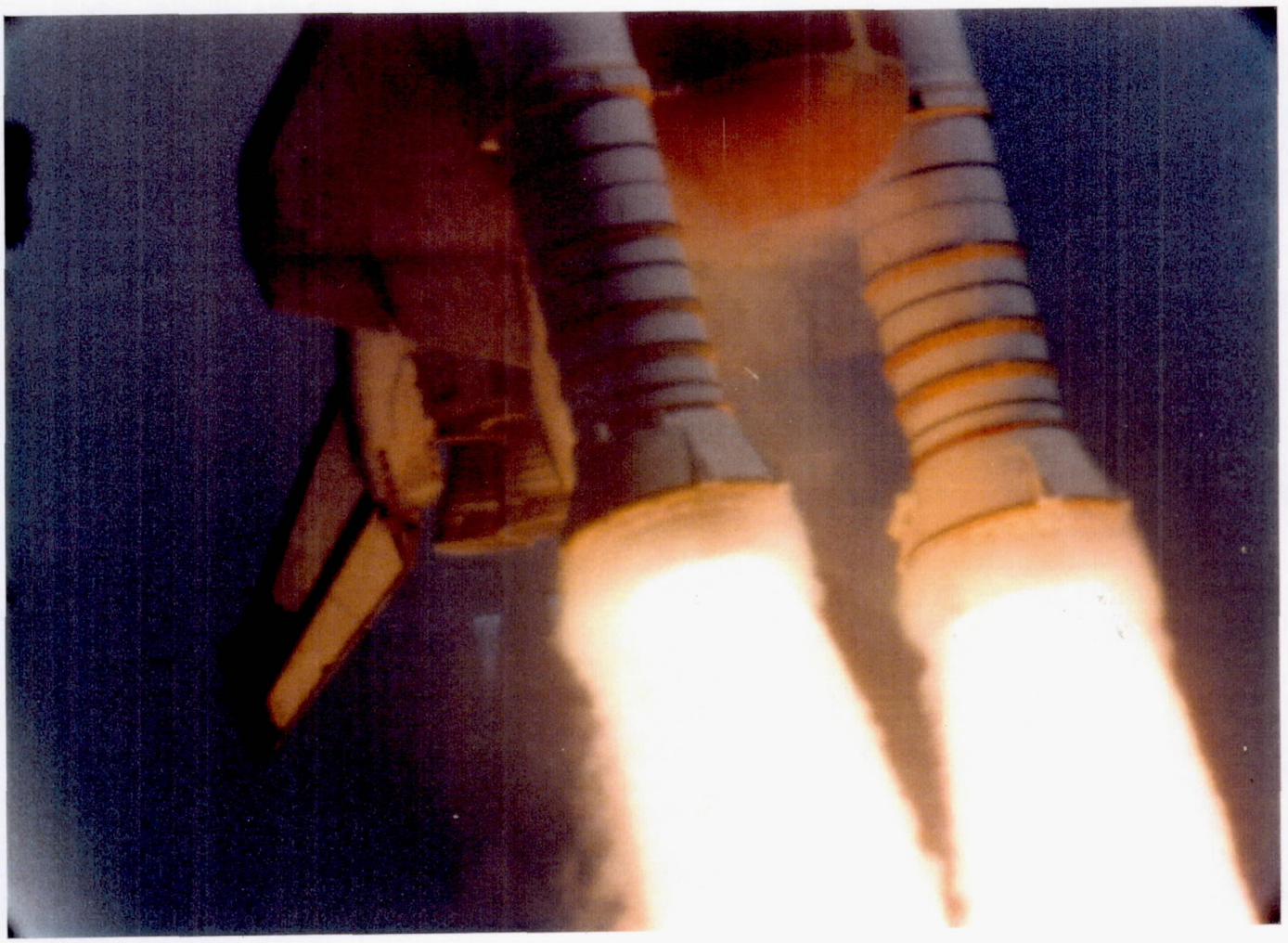


Photo 10: View from Playalinda DOAMS

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

OV-102 was equipped to carry umbilical cameras: 16mm motion picture with 5 mm lens; 16mm motion picture with 10mm lens; 35mm still views. No data was obtained from the 35mm camera in the LO2 ET/ORB umbilical due to a film jam. Good data was obtained from both 16mm films. Handheld photography by the flight crew, which consisted of fifteen still 35mm images, showed a silhouetted tank backlit by the sun.

SRB separation from the External Tank appeared nominal.

ET-84 separation from the Orbiter also appeared normal.

Five TPS divots were visible in the intertank-to-LH2 tank flange closeout in the -Y+Z quadrant outboard of the -Y bipod housing. The divots spanned the entire width of the closeout (9-11 inch diameters), but were not deep enough to show shadow or primed substrate.

Three more TPS divots were detected in the intertank-to-LH2 tank flange closeout between the bipods. Two of the divots were located close to centerline /+Z axis while the third divot appeared to be in the general area of the -Y bipod standoff closeout. These three divots were approximately 6-7 inches in diameter and shallow.

The -Y ET/SRB fairing splice plate closeout was missing a shallow, 3" x 2" area of foam.

The -Y thrust strut was missing 3-inch diameter areas of foam - one on the flange closeout and one just aft of the flange on the barrel.

The LH2 ET/ORB umbilical appeared to be in good condition after separation with no TPS damage. Frozen hydrogen adhered to the 17-inch disconnect and parts of the separation interface. The fire barrier on the outboard side of the LH2 umbilical exhibited two unusually large bubbles that were estimated to be 3" x 2" and 6" x 2", respectively. Typically, foam had eroded from the horizontal (clamshell) section of the cable tray.

Aft dome NCFI 24-57 exhibited typical charring, but less "popcorn" divoting, when compared to previous flights.

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 22 films and videos, which included nine 35mm large format films, two 16mm films, and eleven videos, were reviewed.

The landing gear extended properly. The infrared scanners showed no debris falling from the Orbiter during final approach. Left and right main landing gear touchdown was virtually simultaneous at approximately 3,200 feet from the runway threshold. The Orbiter stayed close to the runway centerline during rollout.

Drag chute deployment appeared nominal.

Touchdown of the nose landing gear was smooth. Rollout and wheel stop were uneventful.

No significant TPS damage was visible in the films.

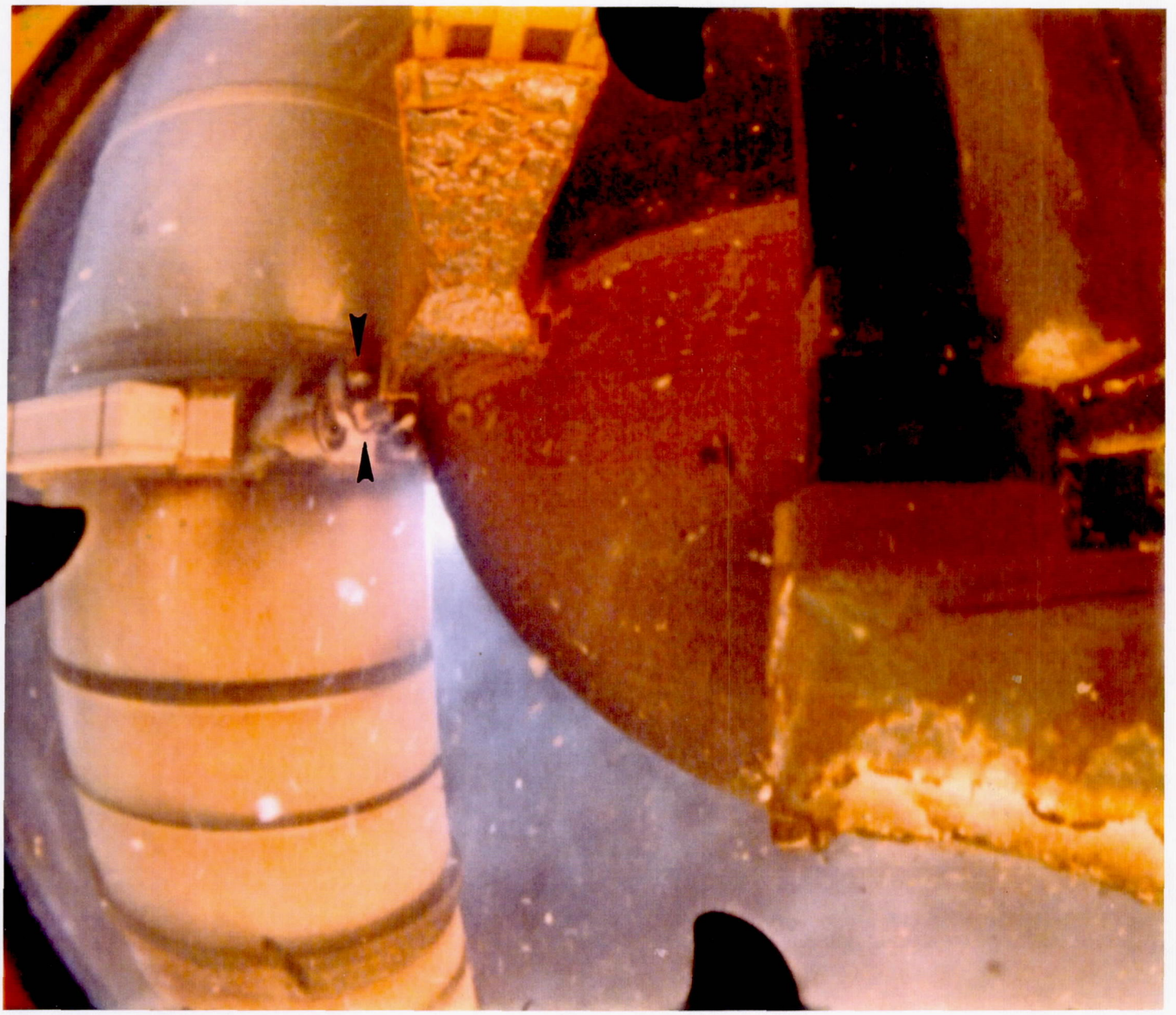


Photo 11: Normal Separation of Left SRB from ET

Foam missing from the upper strut fairing closeouts left shallow divots

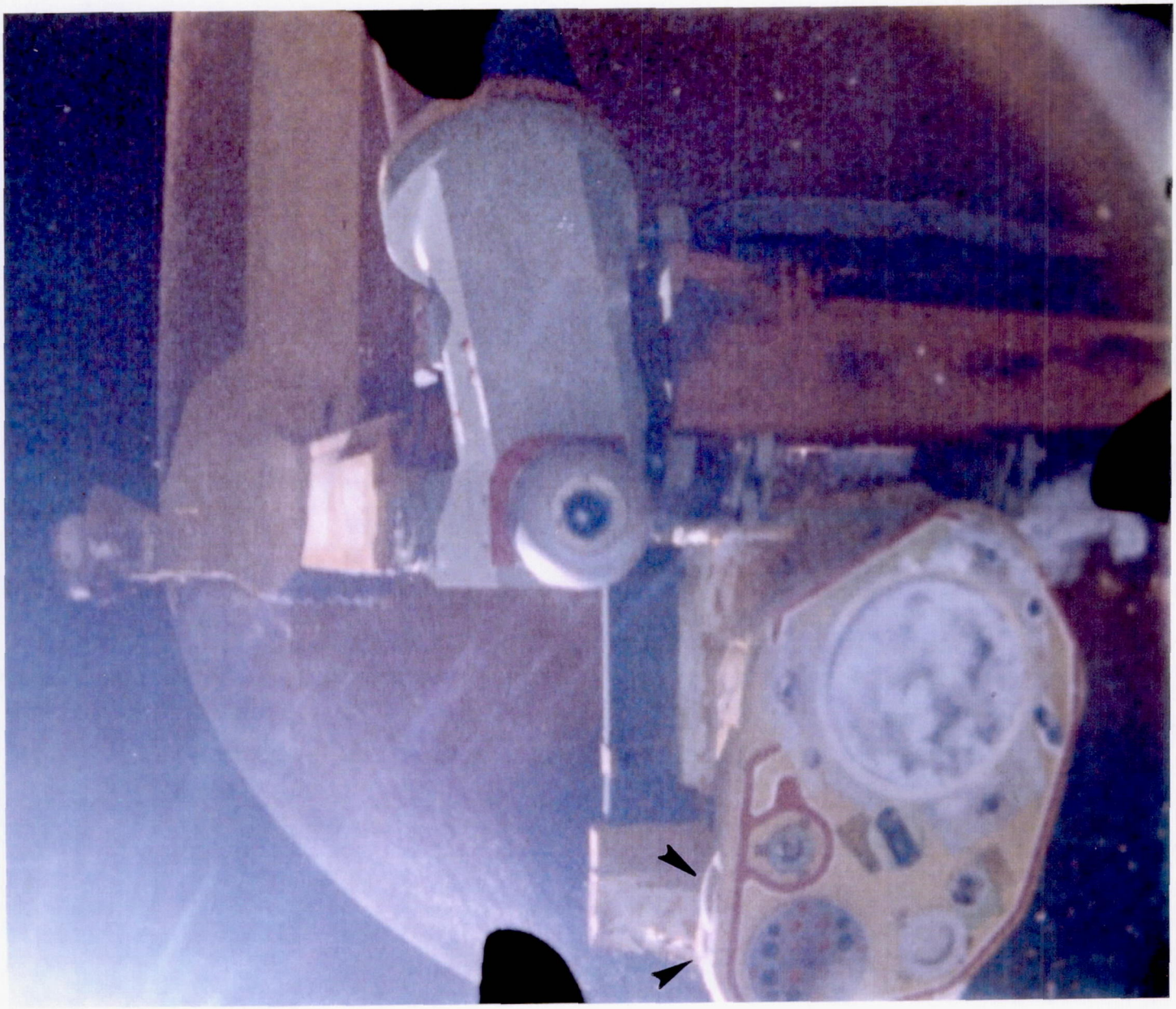


Photo 12: LH2 ET/ORB Umbilical

The LH2 ET/ORB umbilical appeared to be in good condition after separation with no TPS damage. Frozen hydrogen adhered to the 17-inch disconnect and parts of the separation interface. The fire barrier on the outboard side of the LH2 umbilical exhibited two unusually large bubbles that were estimated to be 3" x 2" and 6" x 2", respectively. Typically, foam had eroded from the horizontal (clamshell) section of the cable tray.

Photo 13: Pre-Launch View of LH2 Tank-to-Intertank Flange Closeout

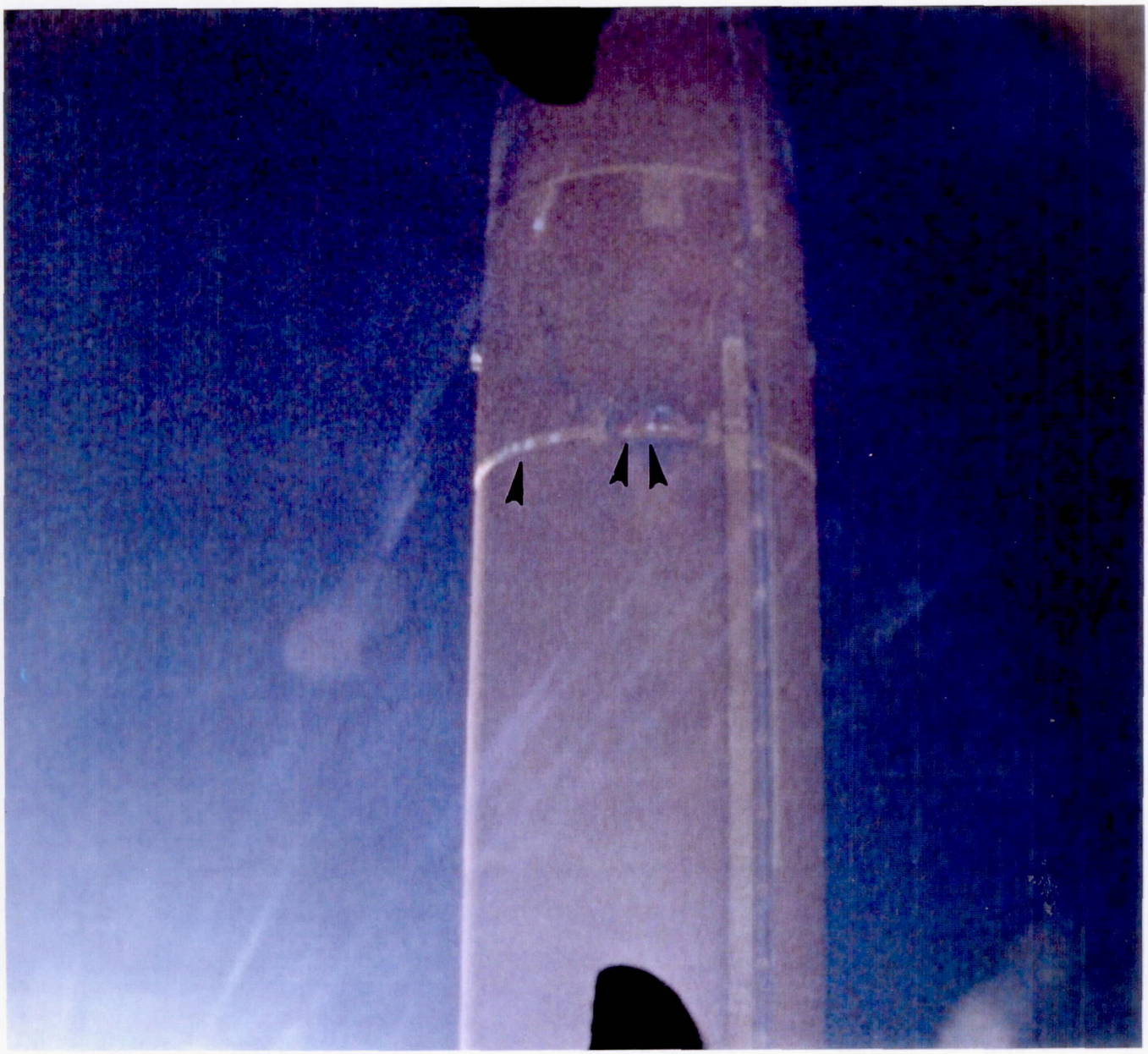


Photo 14: LH2 Tank-to-Intertank Flange Closeout Divots

Five TPS divots were visible in the intertank-to-LH2 tank flange closeout in the -Y+Z quadrant outboard of the -Y bipod housing. The divots spanned the entire width of the closeout (9-11 inch diameters), but were not deep enough to show shadow or primed substrate. Three more TPS divots were detected in the intertank-to-LH2 tank flange closeout between the bipods. Two of the divots were located close to centerline /+Z axis while the third divot appeared to be in the general area of the -Y bipod standoff closeout. These three divots were approximately 6-7 inches in diameter and shallow.

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

The BI-086 Solid Rocket Boosters were inspected for debris damage and debris sources at CCAS Hangar AF on 7 April 1997.

Both frustums were in excellent condition. No TPS was missing and no debonds were detected over fasteners or acreage. None of the Hypalon paint had blistered. All eight BSM aero heat shield covers appeared to be locked in the fully opened position, though all four cover attach rings on the right frustum had been bent by parachute riser entanglement. The upper right cover was missing.

The forward skirts exhibited no debonds or missing TPS. RSS antennae covers/phenolic base plates were intact. The +Z antenna base plate on the right SRB exhibited two delaminated phenolic layers. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips were missing from the frustum severance rings.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ETA ring, IEA, and IEA covers appeared undamaged from splashdown.

TPS on the external surface of both aft skirts was intact and in good condition. Internally, less than usual amounts of foam were missing on the aft skirt aft rings.

Signs of a stud hang-up were evident on the HDP #7 foot with broaching of the bore wall. Stud thread impressions were also present in the wall. Two to four stud thread impressions were also detected in the #2, #3, #5, #6, and #8 bore walls. These thread impressions may have been created during the stacking/tensioning process.

The holddown post Debris Containment Systems (DCS) plungers were seated and appeared to have functioned normally with the exception of #5, where the plunger was obstructed by the frangible nut halves. This condition may have been the result of splashdown.

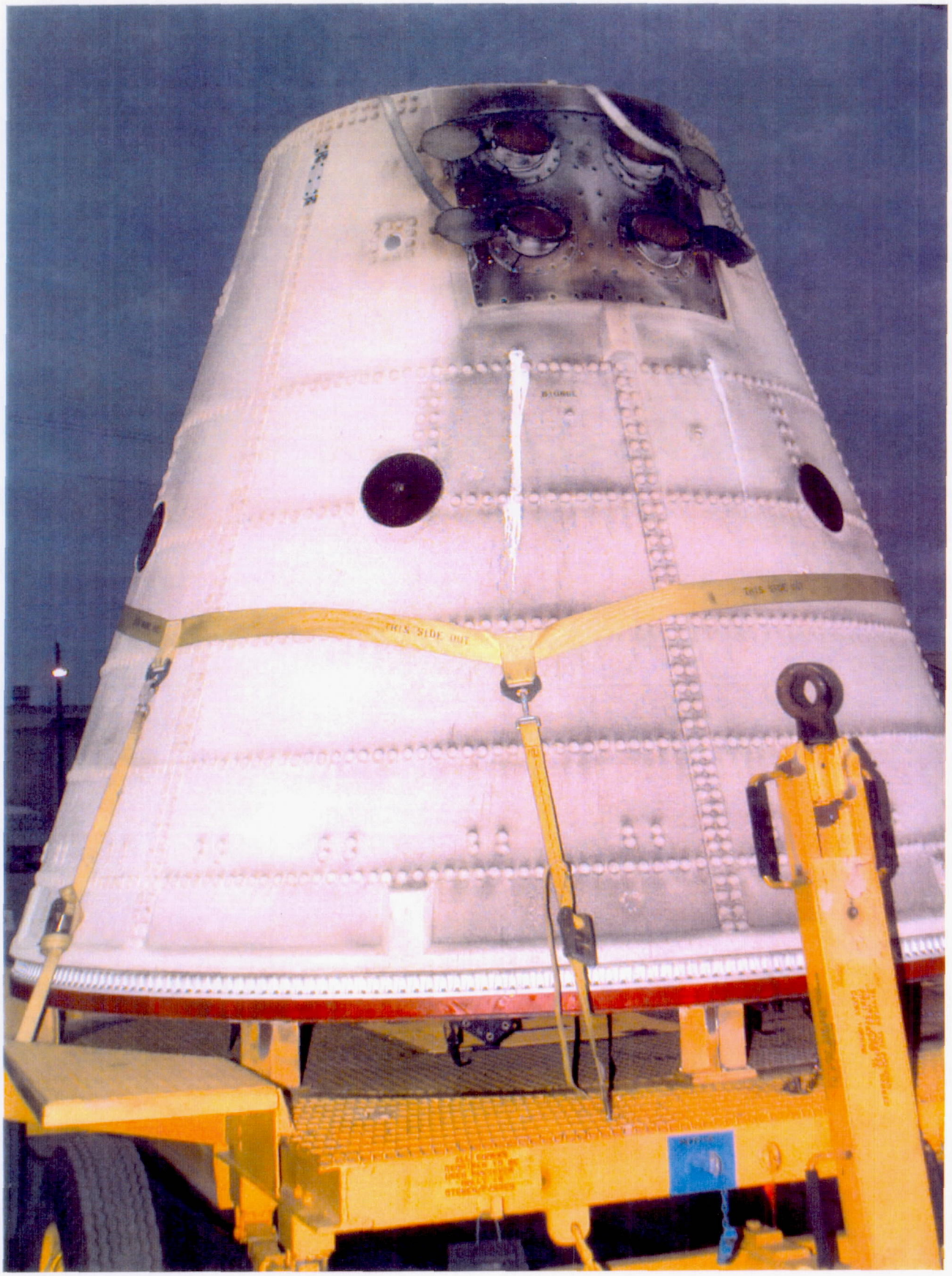


Photo 15: Left Frustum

The left frustum was in excellent condition. No TPS was missing and no debonds were detected over fasteners or acreage. None of the Hypalon paint had blistered. All four BSM aero heat shield covers appeared to be locked in the fully opened position.

Photo 16: Right Frustum

The right frustum was in excellent condition. No TPS was missing and no debonds were detected over fasteners or acreage. None of the Hypalon paint had blistered.

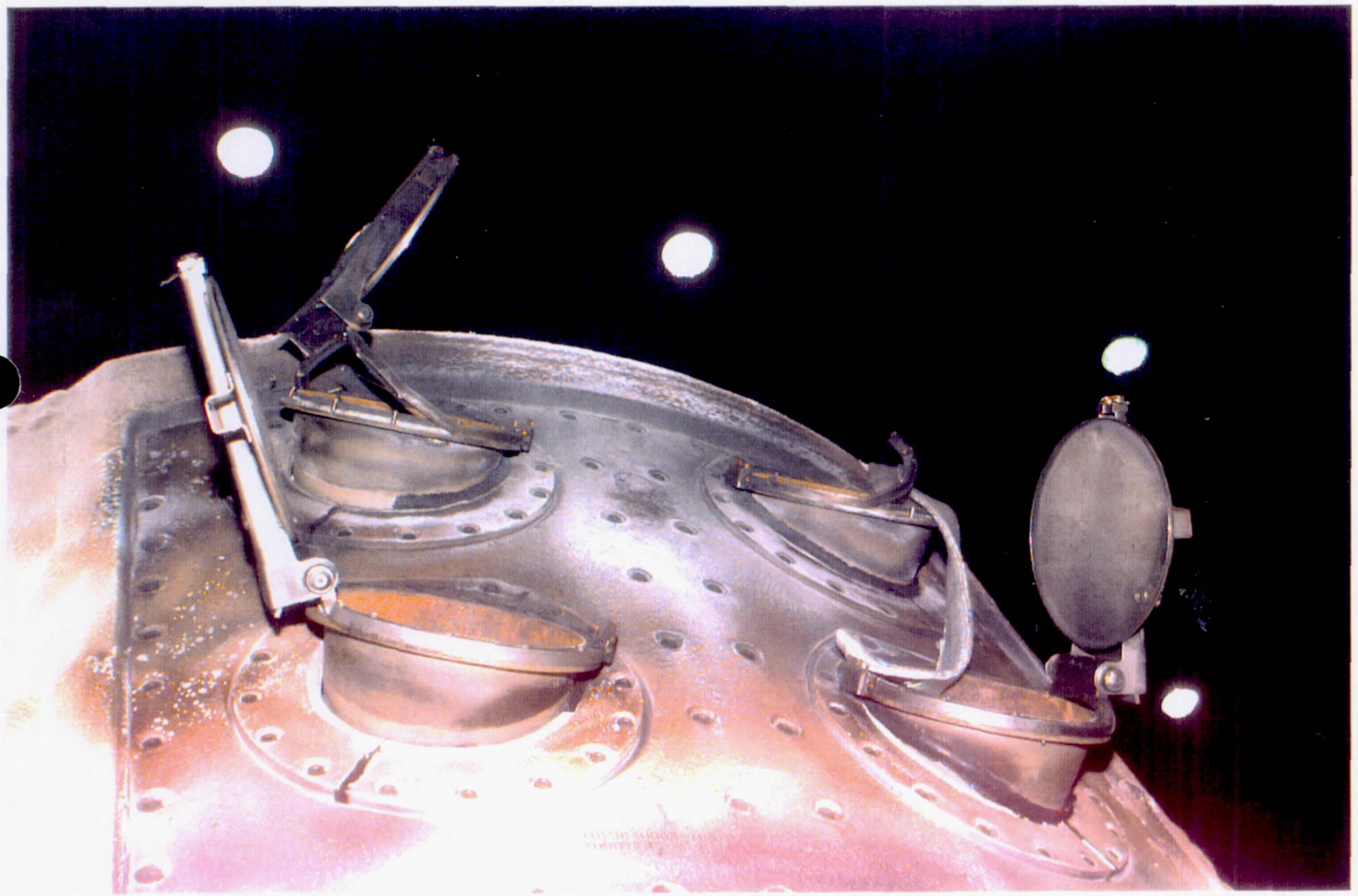


Photo 17: Right Frustum BSM's

All four BSM aero heat shield covers on the right frustum appeared to be locked in the fully opened position, though all four cover attach rings had been bent by parachute riser entanglement. The upper right cover was missing.

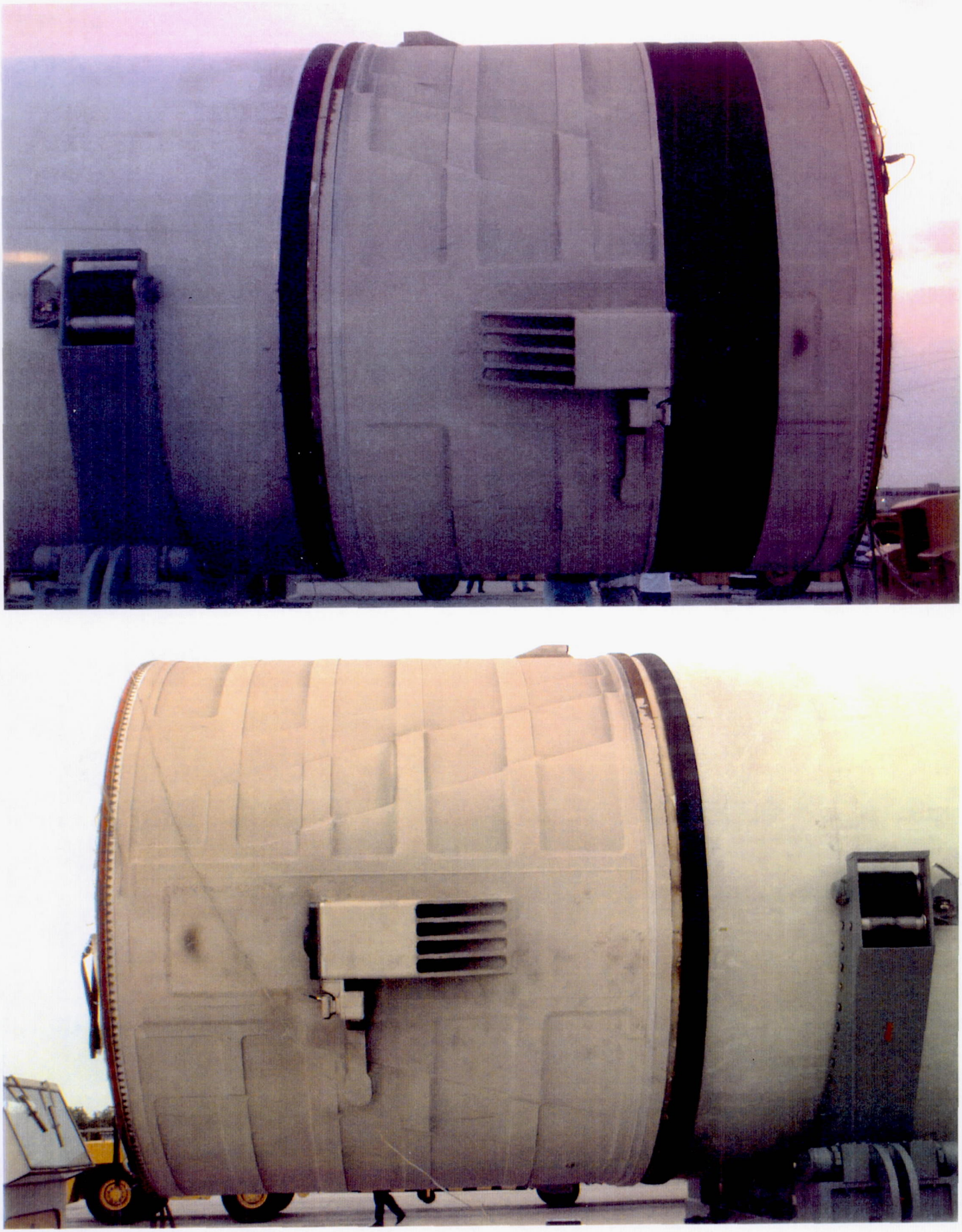


Photo 18: Left and Right Forward Skirts

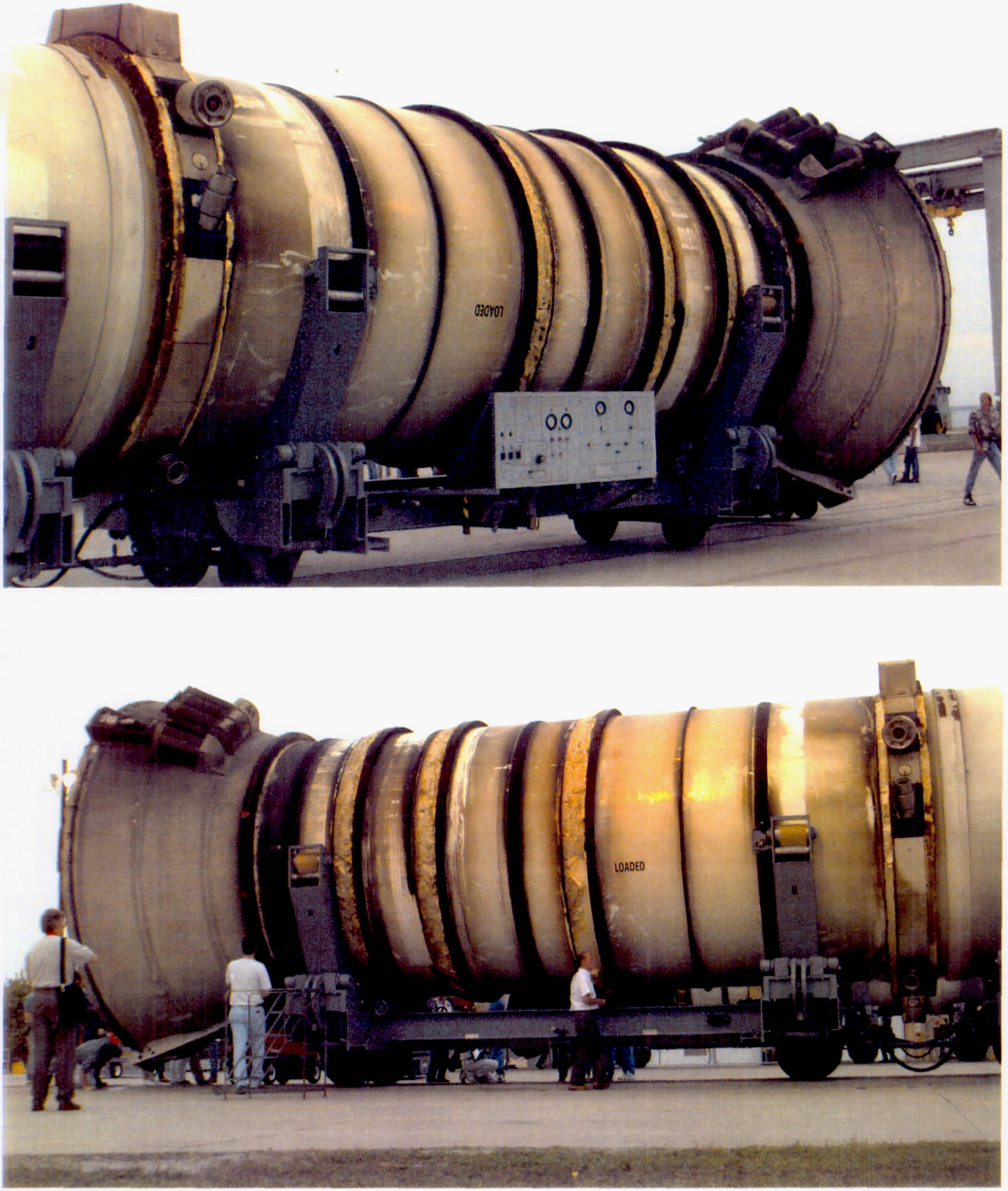


Photo 19: Left and Right Aft Boosters

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing inspection of OV-102 Columbia was conducted 8-10 April 1997 at the Kennedy Space Center on SLF runway 33 and in the Orbiter Processing Facility bay #1. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 81 hits, of which 13 had a major dimension of 1-inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 67 previous missions of similar configuration (excluding missions STS-23, 24, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates both the total number of hits and the number of hits 1-inch or larger were less than average (Reference Figures 1 and 2. Note: since no debris hits were recorded on both left and right sides of the Orbiter, these two figures have been omitted).

The following table breaks down the STS-83 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	7	38
Upper surface	6	36
Right side	0	0
Left side	0	0
Right OMS Pod	0	2
Left OMS Pod	0	5
TOTALS	13	81

The Orbiter lower surface sustained a total of 38 hits, of which 7 had a major dimension of 1-inch or larger. The largest lower surface tile damage site was located on the body flap. The site measured 2-inches long by 1-inch wide by 0.125-inch maximum depth. The damage was probably caused by an impact from ET/ORB umbilical ice.

Tile damage sites aft of the LH2 and LO2 ET/ORB umbilicals were typical in size and quantity. The damage was most likely caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the airstream, both of which were observed in launch films.

No tile damage from micrometeorites or on-orbit debris was identified during this inspection.

The tires and brakes were reported to be in good condition for a landing on the KSC concrete runway. There was some ply undercutting on two of the MLG tires.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. No ordnance fragments were found on the runway beneath the umbilical cavities. Virtually no umbilical closeout foam or white RTV dam material adhered to the umbilical plate near the LH2 recirculation line disconnect. EO-2 and EO-3 retainer springs were bent. This condition has been observed on previous flights.

Bent metal, approximately 1-inch in length by 1/4-inch wide, was visible on the trailing edge of a spacer between two bolt heads on the inside surface of the LO2 ET door near the forward outboard corner. This same condition has occurred after the last three flights on different Orbiters.

The SSME Dome Mounted Heat Shield (DMHS) closeout blankets were in excellent condition.

Damage to base heat shield tiles, attributed to SSME vibration/acoustics and exhaust plume recirculation, was typical. A corner was missing from a tile located in the area between SSME #2, SSME #3, and the body flap hinge.

Tiles on the vertical stabilizer "stinger" and around the drag chute cavity were undamaged.

No ice adhered to the payload bay door. No significant tile damage occurred on the leading edges of the OMS pods or vertical stabilizer.

Hazing and streaking of forward-facing Orbiter windows was typical. Damage sites on the window perimeter tiles appeared to be greater than usual in quantity and size. Two damage sites greater than 1-inch in size within a cluster of 11 hits were present in the black tile area between windows #3 and #4. These damage sites are believed to be the result of impacts from excessive RTV adhesive used in attaching paper covers to the FRCS thrusters.

The post landing walkdown of Runway 33 was performed immediately after landing. No debris concerns were identified. All drag chute hardware was recovered and appeared to have functioned normally.

In summary, both the total number of Orbiter TPS debris hits and the number of hits 1-inch or larger were less than average when compared to previous missions (Reference Figure 3).

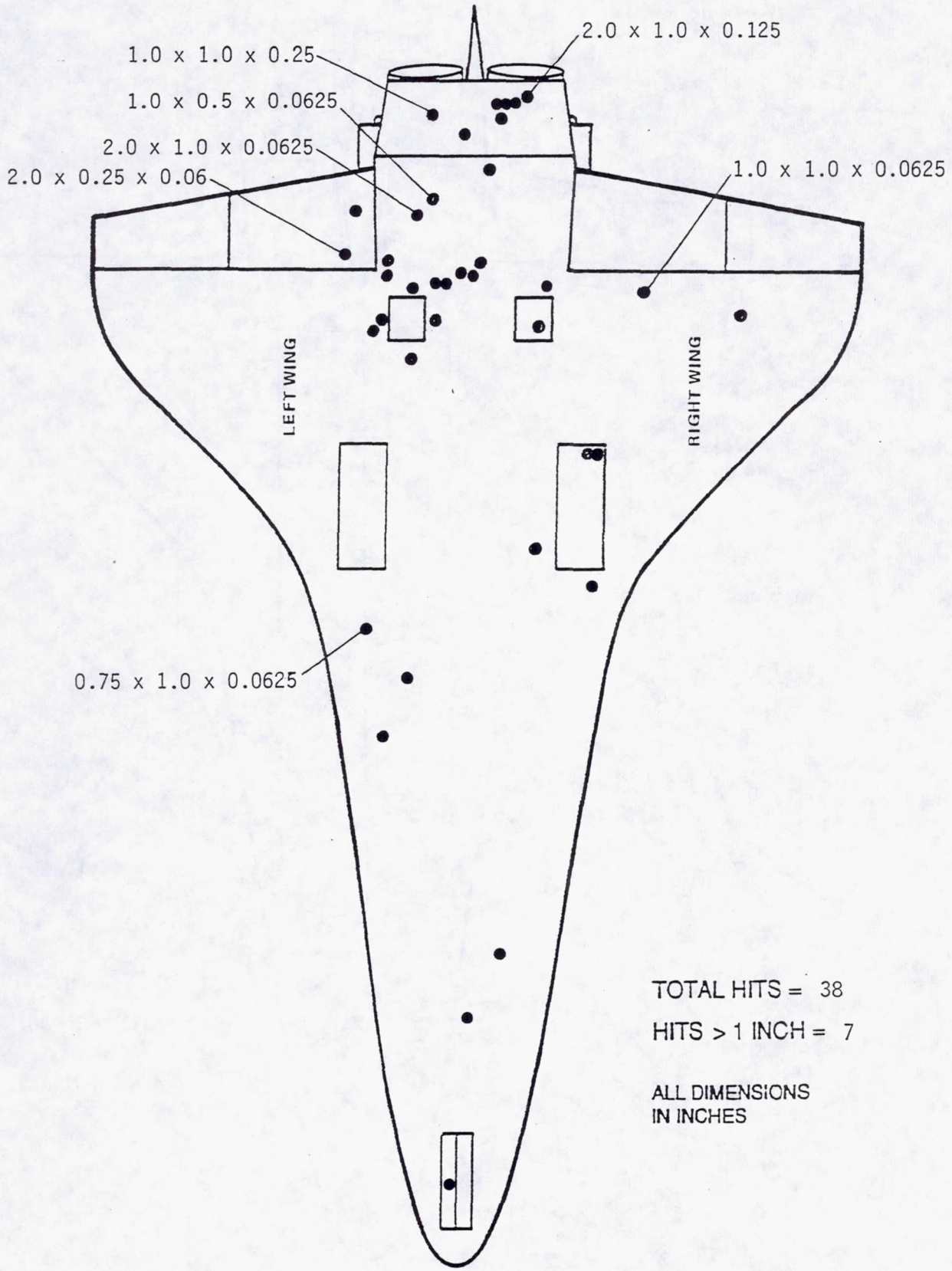


Figure 1: Orbiter Lower Surface Debris Damage Map

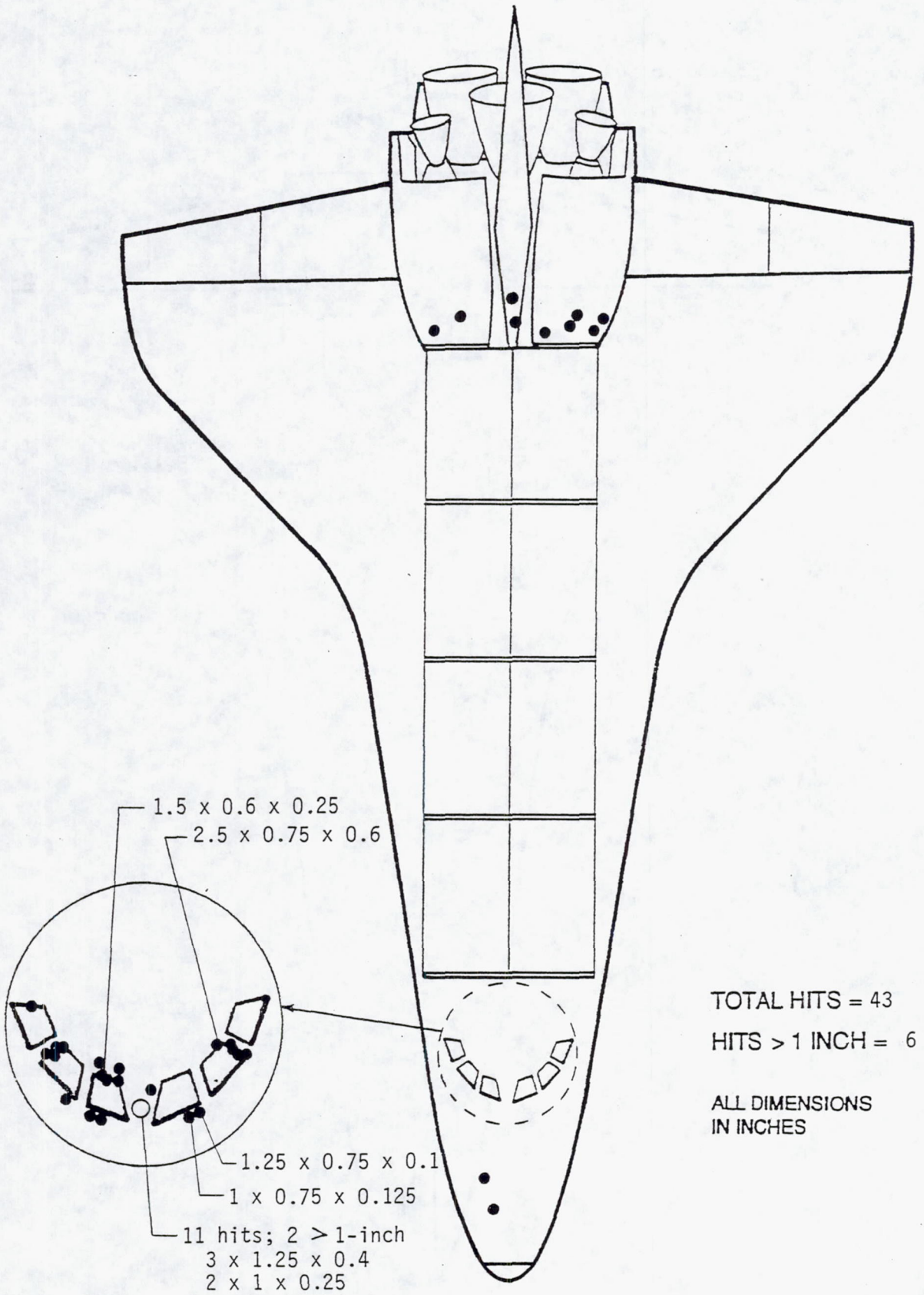


Figure 2: Orbiter Upper Surface Debris Damage Map

	LOWER SURFACE		ENTIRE SURFACE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	21	89	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156

	LOWER SURFACE		ENTIRE SURFACE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-55	10	128	13	143
STS-57	10	75	12	106
STS-51	8	100	18	154
STS-58	23	78	26	155
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
STS-59	10	47	19	77
STS-65	17	123	21	151
STS-64	18	116	19	150
STS-68	9	59	15	110
STS-66	22	111	28	148
STS-63	7	84	14	125
STS-67	11	47	13	76
STS-71	24	149	25	164
STS-70	5	81	9	127
STS-69	22	175	27	198
STS-73	17	102	26	147
STS-74	17	78	21	116
STS-72	3	23	6	55
STS-75	11	55	17	96
STS-76	5	32	15	69
STS-77	15	48	17	81
STS-78	5	35	12	85
STS-79	8	65	11	103
STS-80	4	34	8	93
STS-81	14	48	15	100
STS-82	14	53	18	103
AVERAGE	13.6	85.6	20.0	126.1
SIGMA	7.2	44.0	9.6	52.8
STS-83	7	38	13	81

MISSIONS STS-23,24,25,26,26R,27R,30R,AND42R ARE NOT INCLUDED IN THIS ANALYSIS
SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

Figure 3: Orbiter Post Flight Debris Damage Summary

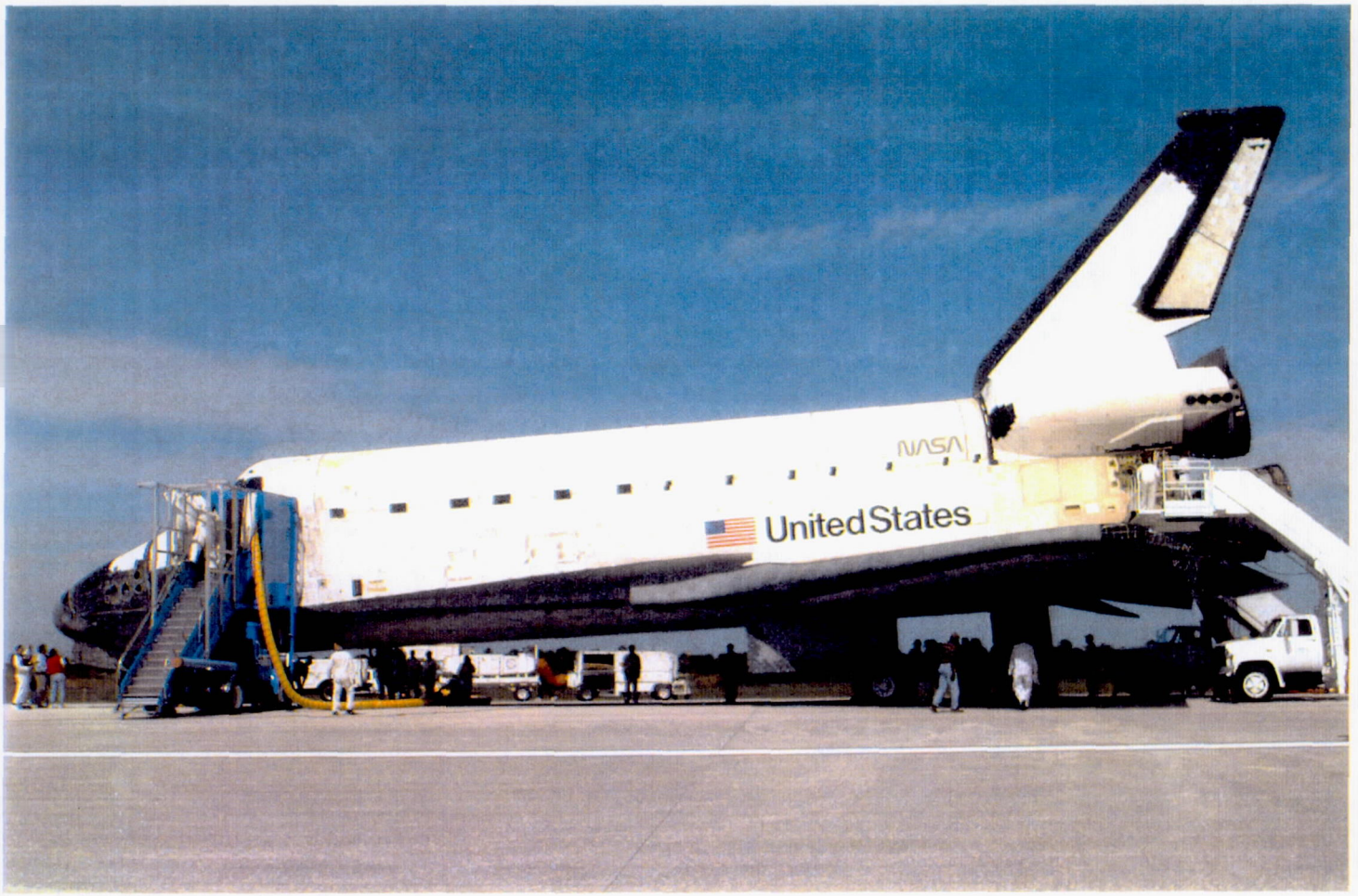


Photo 20: Overall View Orbiter Left Side

Photo 21: Overall View Orbiter Right Side

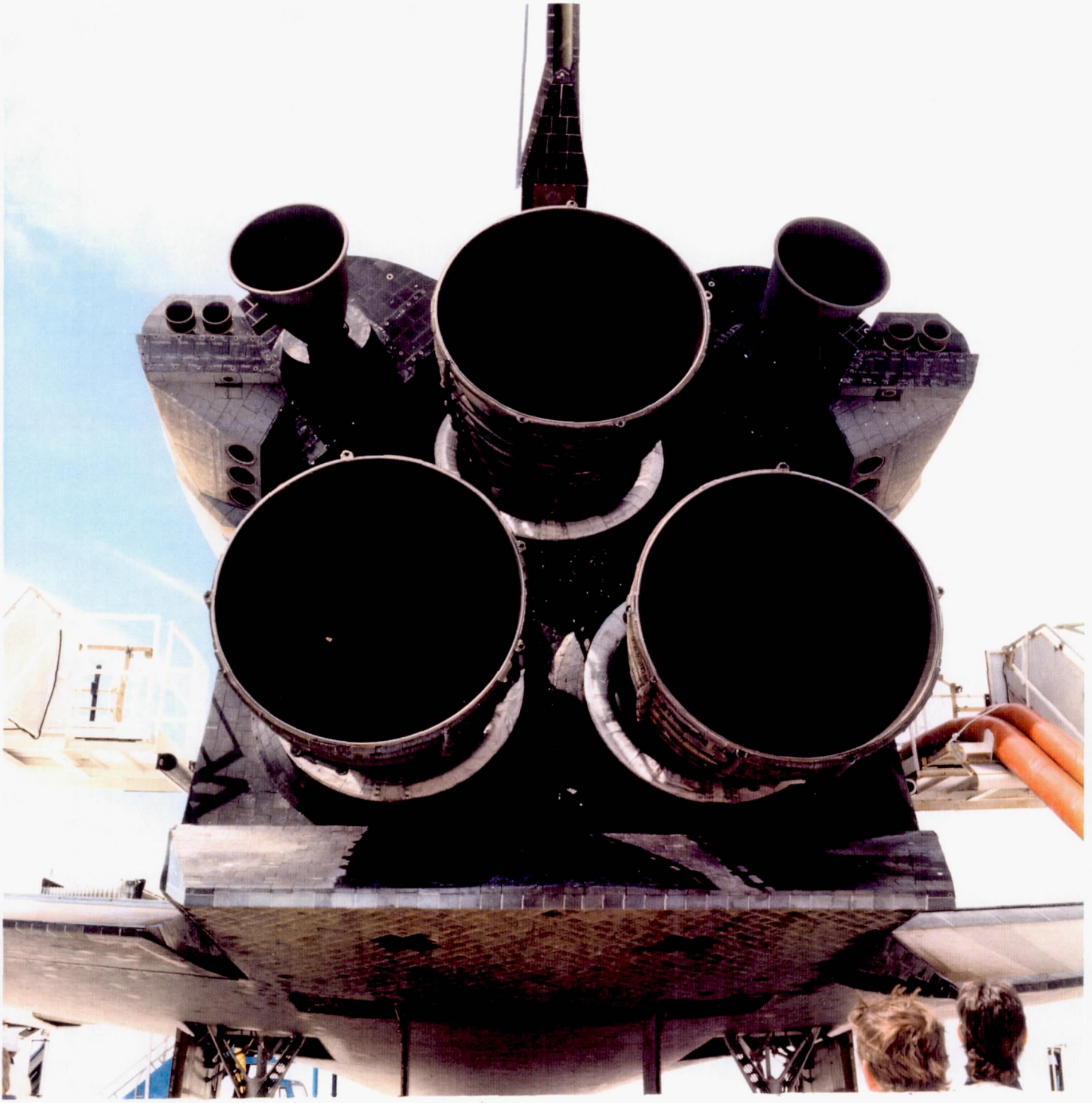


Photo 22: Overall View Orbiter Base Heat Shield and SSME's

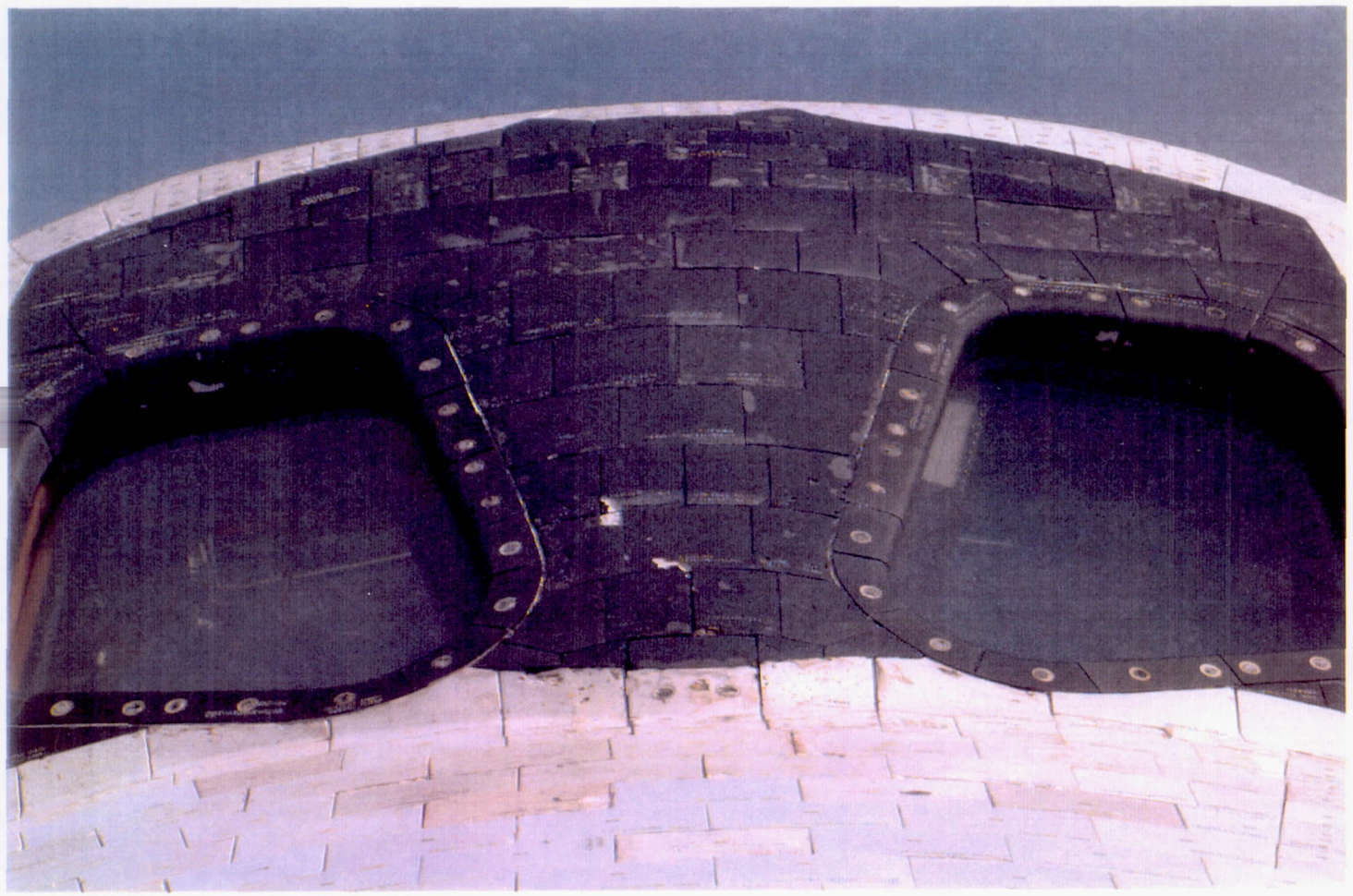


Photo 23: Orbiter Windows #3 and #4

Hazing and streaking of forward-facing Orbiter windows was typical. Damage sites on the window perimeter tiles appeared to be greater than usual in quantity and size. Two damage sites greater than 1-inch in size within a cluster of 11 hits were present in the black tile area between windows #3 and #4. These damage sites are believed to be the result of impacts from excessive RTV adhesive used in attaching paper covers to the FRCS thrusters.

Photo 24: LO2 ET/ORB Umbilical

Photo 25: LH2 ET/ORB Umbilical

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY

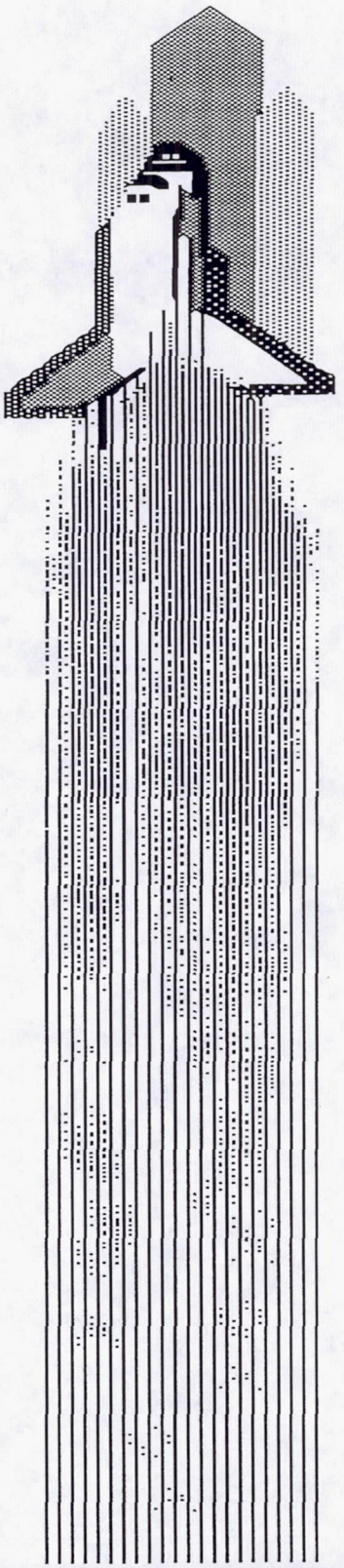
Space Shuttle

Earth Science Branch

Image Science and
Analysis Group

STS-83 Summary of Significant Events

May 8, 1997



Space Shuttle
Image Science and
Analysis Group

STS-83 Summary of Significant Events

Project Work Order - SN-5LA

Approved By

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Earth Science Branch
Earth Science and Solar System Exploration Division
Space and Life Sciences Directorate

Table of Contents

List of Tables and Figures

1. STS-83 (OV-102): FILM/VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

The STS-83 daytime launch of Columbia (OV-102) from pad A occurred on Friday, April 4, 1997 (day 094) at 19:20:32.029 Coordinated Universal Time (UTC), as seen on camera E8. Solid Rocket Booster (SRB) separation occurred at 19:22:34.933 UTC, as seen on camera KTV13.

On launch day, 24 of the 24 expected videos were received and screened. Following launch day, twenty-one films were screened. Twenty-two additional films were received for contingency support and anomaly resolution, but were not screened since there were no major launch/ascent issues. No anomalies that could threaten vehicle safety were seen on the launch imagery.

Detailed Test Objective 312 was performed using umbilical well film (Method 1) and handheld still photography (Method 4).

1.1.1 On-Orbit

No on-orbit analysis support was requested.

1.1.2 Landing

The STS-83 flight was terminated after four days because a fuel cell exhibited an unacceptable internal voltage differential. Columbia landed in the afternoon on runway 33 at the KSC Shuttle Landing Facility on April 8, 1997. Eleven videos were received and screened. Following landing, eleven films were screened. Camera view SLF-North was not received.

No anomalies were noted in the approach, landing, or roll-out video and film views screened. The drag chute deployment appeared normal.

Contrails were seen trailing from the Orbiter wing tips prior to landing (Camera KTV6L).

1.1.3 Post Landing

The following items were seen on the post landing walk-around video: erosion/chipping of the surface area of several tiles on the base heat shield, tile damage on the upper surface of the body flap, a partially-dislodged piece of metal on the inner surface of the LO2 umbilical well door, tile damage on the upper perimeter tiles of Orbiter forward windows 3 and 4, tile damage between windows 3 and 4, and small abrasion marks on the main landing gear tires.

1.2 TIMING ACTIVITIES

The time codes from videos were used to identify specific events during the initial screening process.

The landing and drag chute event times are provided in Table 1.2.

Event Description	Time (UTC)	Camera
Landing Gear - Doors Opened	98:18:32:48.633	KTV6L
Right Main Wheel Touchdown	98:18:33:10.400	KTV33L
Left Main Wheel Touchdown	98:18:33:10.500	KTV33L
Drag Chute Initiation	98:18:33:15.133	KTV11L
Pilot Chute at Full Inflation	98:18:33:16.000	KTV33L
Bag Release	98:18:33:16.667	KTV11L
Drag Chute Inflation in Reefed Configuration	98:18:33:17.600	KTV33L
Drag Chute Inflation in Disreefed Configuration	98:18:33:20.833	KTV33L
Nose Wheel Touchdown	98:18:33:22.367	KTV33L
Drag Chute Release	98:18:33:47.800	KTV33L
Wheel Stop	98:18:34:09.900	KTV15L

Table 1.2 Landing Video Event Timing

2. SUMMARY OF SIGNIFICANT EVENTS

2.1 DEBRIS FROM SSME IGNITION TO LIFTOFF

As on previous missions, multiple pieces of debris were seen near the time of SSME ignition to liftoff (umbilical ice debris, RCS paper, SRB flame duct debris). No damage to the vehicle was noted. No follow-up action was requested.

A thin, flat, irregular-shaped piece of debris (possibly a paint chip) was seen close to camera E19 prior to liftoff (19:20:27.659 UTC).

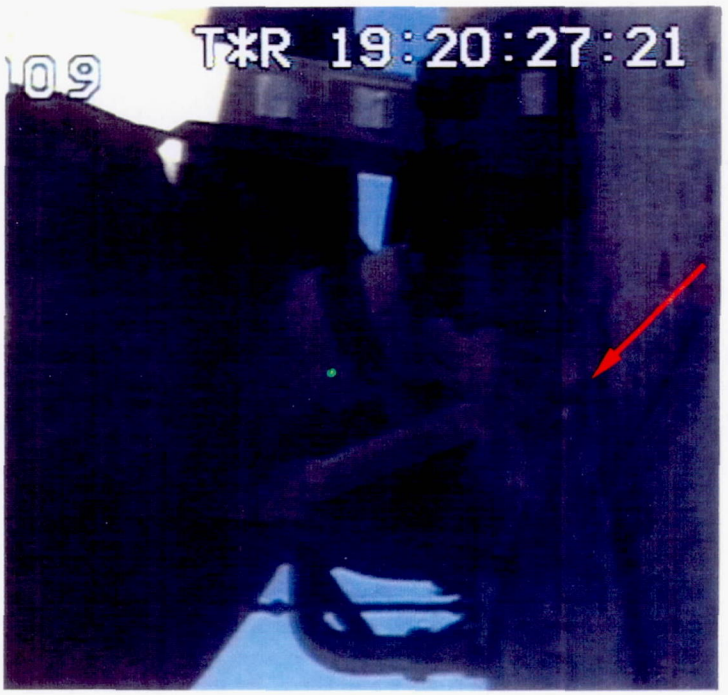


Figure 2.1 (A) Ice Debris Strike to Umbilical Well Door Sill

Multiple pieces of ice debris from the LH2 ET/Orbiter umbilical were seen falling past the body flap during SSME ignition. Ice debris was seen to strike the LH2 umbilical well door sill (19:20:27.7 UTC). No damage was noted (Camera OTV009).

Several light-colored pieces of debris were seen near the LSRB/ET aft attach ring prior to SRB ignition (19:20:30.802 UTC), (Camera E31).

2.2 DEBRIS DURING ASCENT

During ascent, multiple pieces of debris (probably umbilical ice and RCS paper) fell aft of the launch vehicle after liftoff, through the roll maneuver, and beyond. No damage to the vehicle was noted. No follow-up action was requested. (Cameras E31, E34, E52, E54, E76, E222, E223, E224).

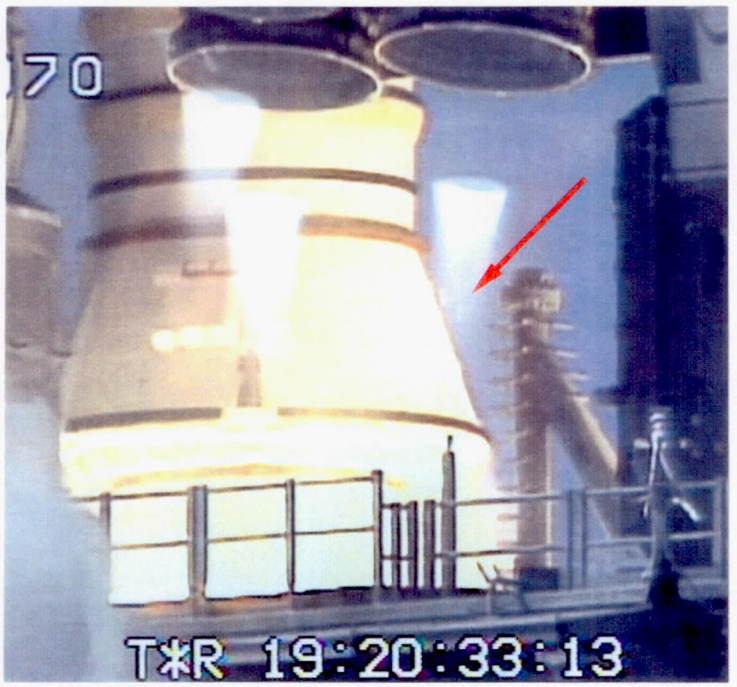


Figure 2.2 (A) Light-Colored Debris Near RSRB

Light-colored debris (probably umbilical ice) was seen near the RSRB aft skirt at 19:20:33.433 UTC (Camera OTV070).

A loose piece of thermal curtain tape was seen on the RSRB during liftoff (19:20:33.8 UTC), (Cameras E1, E5, E52).

White debris, first seen near the ET/Orbiter forward attach bipod, fell aft between the Orbiter and the ET after liftoff (19:20:35.067 UTC). The debris was not seen to contact the vehicle (Camera OTV061).

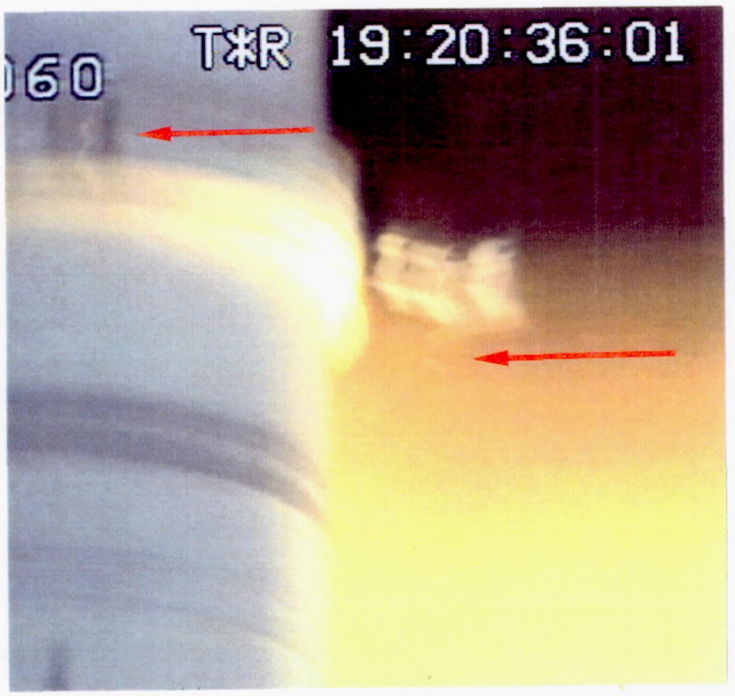


Figure 2.2 (B) Debris Near RSRB Aft ET attach Ring

Two pieces of light-colored debris were seen near the RSRB aft ET attach ring during liftoff (19:20:36.033 UTC), (Camera OTV060).

A single piece of SRB flame duct debris (probably RCS paper) was seen north of the launch vehicle during liftoff (19:20:48.255 UTC), (Cameras E5, E19, E52).

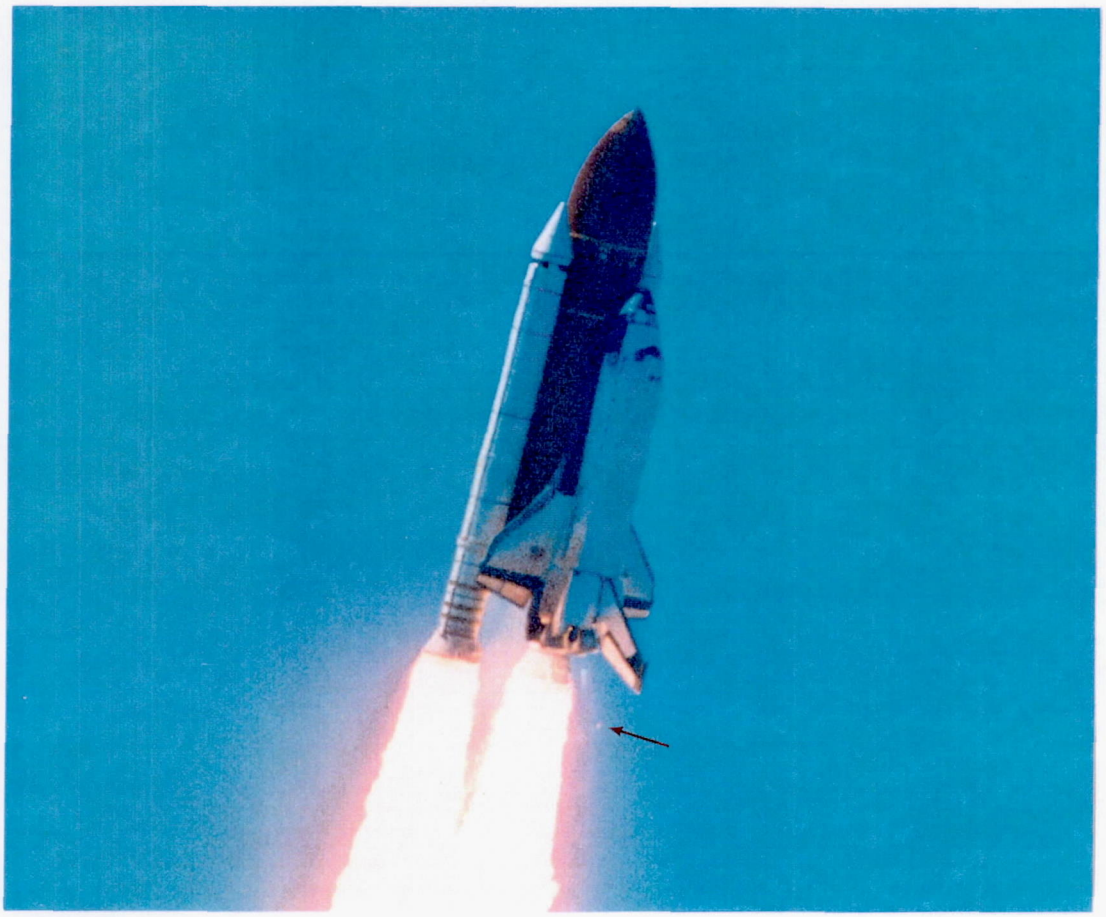


Figure 2.2 (C) Debris Aft of Vertical Stabilizer

A single piece of debris fell aft of the vertical stabilizer during ascent (19:20:49.550 UTC), (Camera E222).

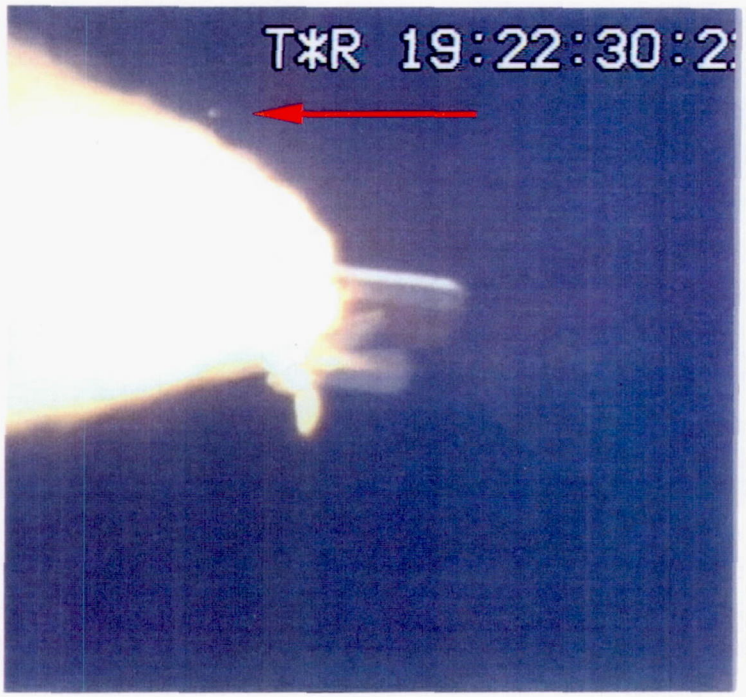


Figure 2.2 (D) Debris Near SRB Exhaust Plume During Ascent

Multiple pieces of debris (possible SRB aft skirt insta-foam) were seen falling along the SRB exhaust plume during ascent. The debris were seen at 19:20:50.433, 19:20:51.4, 19:20:53.2, 19:21:39.2, and 19:22:30.733 UTC (Cameras KTV4A, KTV13, KTV21A, ET204, ET212, E224).

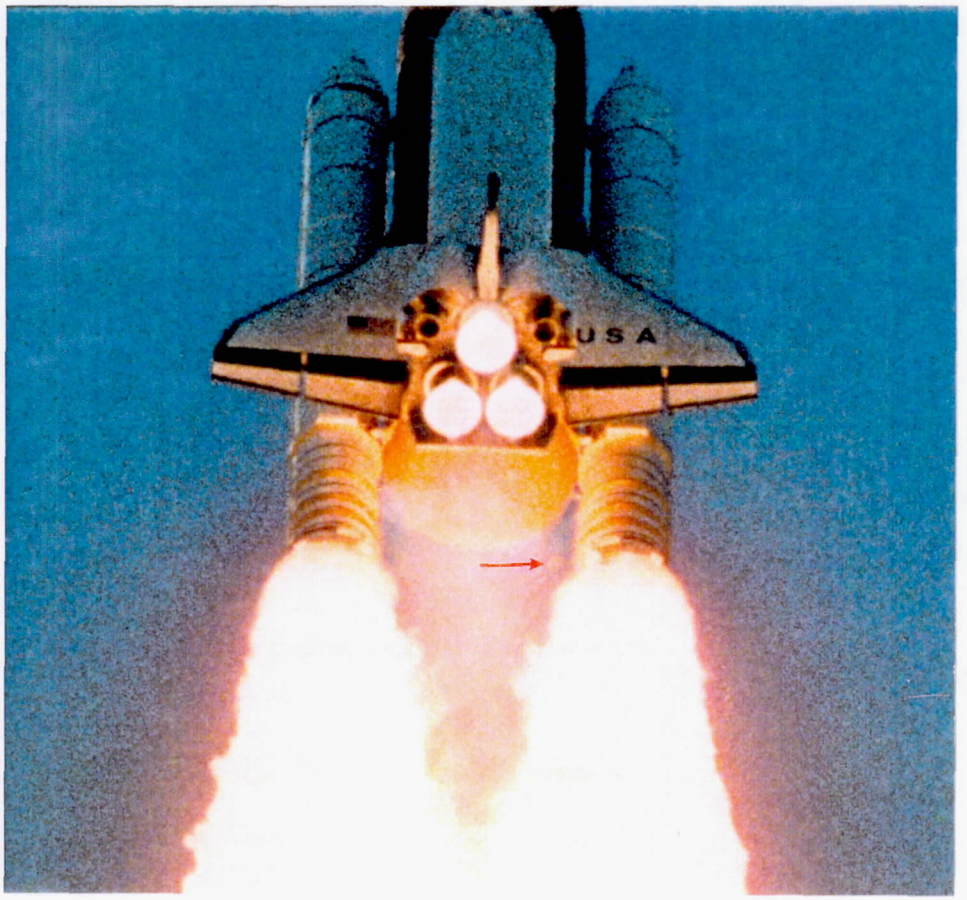


Figure 2.2 (E) Debris Near ET Dome and RSRB

Six relatively large pieces of debris (probably umbilical purge barrier material), first seen near the ET aft dome and the RSRB aft attach ring, fell between SRBs during ascent (19:20:50.604 UTC), (Cameras E52, E54).

2.3 MOBILE LAUNCH PLATFORM (MLP) EVENTS

The SSME Mach diamond formation appeared to occur out of sequence as seen on Camera E76. No follow-up action was requested. The times of the Mach diamond formation are provided in Table 2.3.

SSME #3	19:20:28.764 UTC
SSME #1	19:20:28.962 UTC
SSME #2	19:20:29.032 UTC

Table 2.3 (A) Mach Diamond Formation

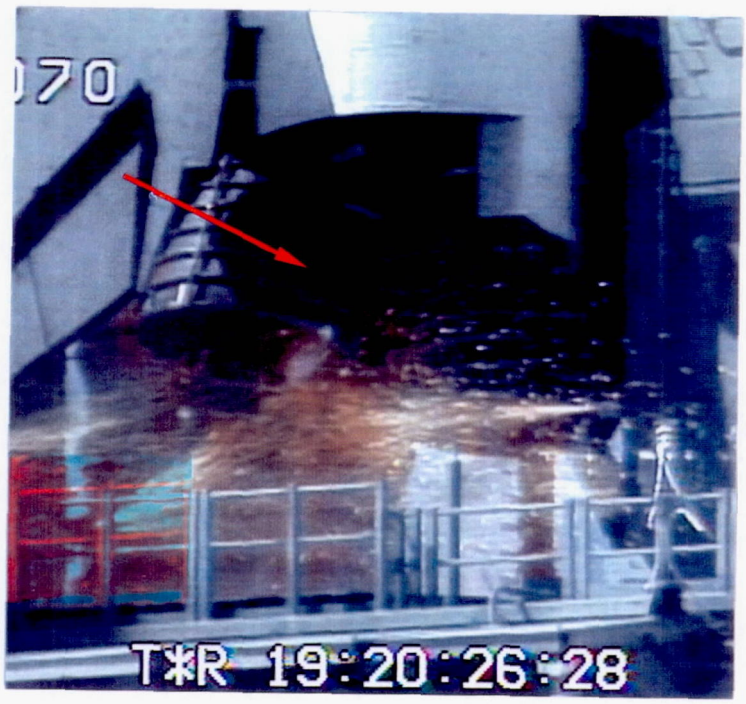


Figure 2.3 (A) Orange Vapor During SSME Ignition

Orange vapor, probably free burning hydrogen, was seen above the SSME rims and near the base of the vertical stabilizer during SSME ignition (19:20:26.9 UTC). Orange vapors have been seen on previous missions (Camera OTV070).

Figure 2.3 (B) Holddown Post M-7 Bolt Hang-Up

A bolt hang-up was seen at the LSRB holddown post M-7 at liftoff (19:20:32.611 UTC), (Camera E11). An unidentified piece of debris fell past the HDP shoe at 19:20:32.601 UTC. SRB holddown bolt hang-ups have been seen on six of the last eleven previous missions. See Table 2.3 (B). No follow-up action was requested.

MISSION	LOCATION OF HANG-UP
STS-34	RSRB holddown post M-2
STS-33	RSRB holddown post M-3
STS-39	RSRB holddown post M-1
STS-43	LSRB holddown post M-7
STS-45	RSRB holddown post M-4
STS-50	RSRB holddown post M-4
STS-46	LSRB holddown post M-7
STS-53	RSRB holddown post M-1
STS-73	RSRB holddown post M-2
STS-75	LSRB holddown post M-5
STS-76	LSRB holddown post M-5
STS-78	LSRB holddown post M-5
STS-79	RSRB holddown post M-3
STS-83	LSRB holddown post M-7

Table 2.3 (B) Table of Holddown Post Bolt-Hang-ups

TPS base heat shield erosion was noted between the OMS pod and the base of SSME #3 during SSME ignition (19:20:27.659 UTC), (Camera E19).

2.4 ASCENT EVENTS

Atmospheric condensation was seen around the Shuttle Launch Vehicle during ascent (19:21:10 through 19:21:20 UTC), (Cameras ET207, ET208, ET212, ET213, E207, E212, E222, E223, E224).

Linear optical effects were seen along the launch vehicle between 19:21:33.9 and 19:21:38.5 UTC (Camera ET212, E212).

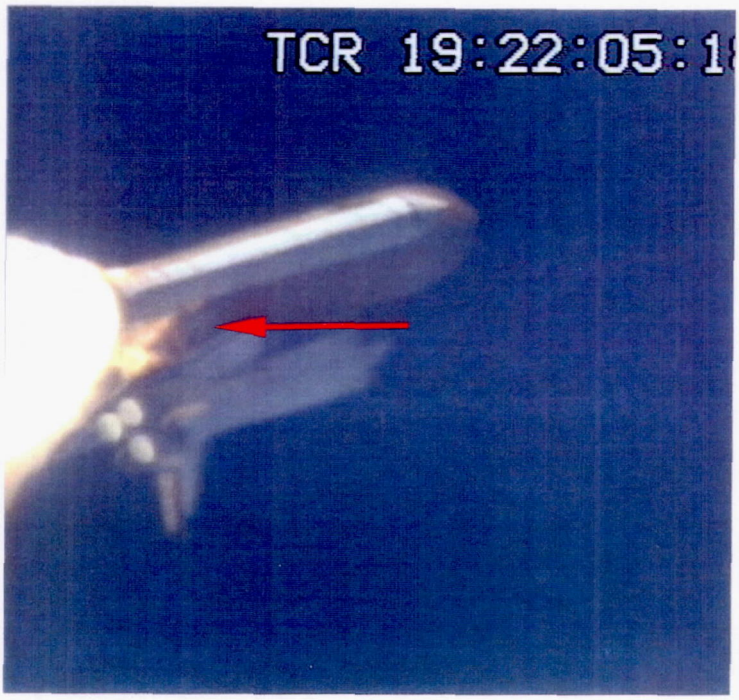


Figure 2.4 Recirculation at Aft End of Vehicle

Recirculation, or the expansion of burning gasses at the aft end of the vehicle, was seen during ascent (19:22:04.7 - 19:22:18.1 UTC). Recirculation during this time period has been seen on previous missions (Cameras KTV13, ET204, ET208, ET212, E212).

A noticeable brightening was seen in the SRB exhaust plume just prior to SRB separation (19:22:30.967 to 19:22:34.033 UTC), (Cameras ET204, ET207).

2.5 ONBOARD PHOTOGRAPHY OF THE EXTERNAL TANK (DTO-312)

2.5.1 Analysis of the Umbilical Well Camera Films (Task #2)

Two rolls of STS-83 umbilical well camera film were acquired (DTO-312, Method 1): the 16mm film (5mm lens) and the 16mm film (10mm lens) from the LH2 umbilical. The 35mm camera film from the LO2 umbilical did not run. The +X translation maneuver was performed on STS-83.

Numerous light-colored pieces of debris (insulation and frozen hydrogen) and dark debris (probably charred insulation) were seen throughout the film sequence. Typical ablation and charring of the ET/Orbiter LH2 umbilical electric cable tray and the aft surface of the horizontal section of the -Y ET/SRB vertical strut was seen. Ablation and charring of the TPS on the aft dome was less than usual. The LSRB separation appeared normal.

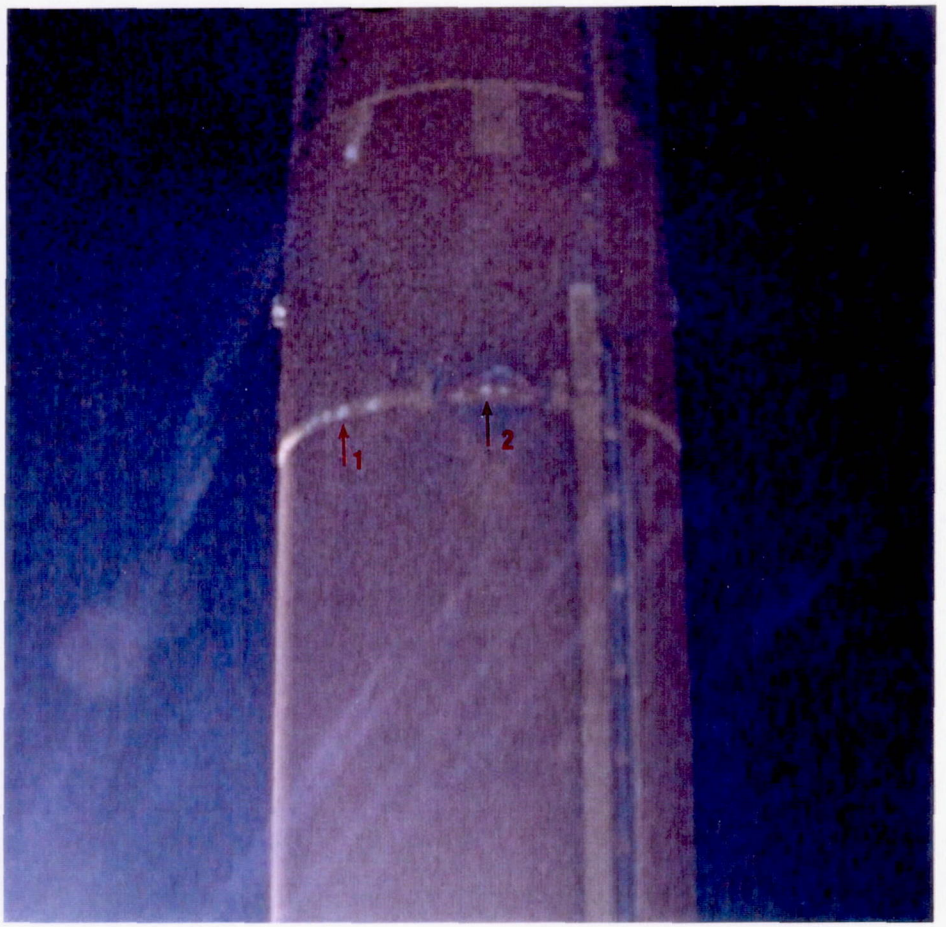


Figure 2.5.1 (A) Closeout Flange Divots

Four TPS divots, approximately nine inches in size, were seen on the intertank-to-LH2 tank flange closeout on the -Y+Z axis (1). Three additional TPS divots (2), approximately six inches in size, were seen on the intertank-to-LH2 tank flange closeout between the bipod legs (2). (10mm lens, frame 10753).

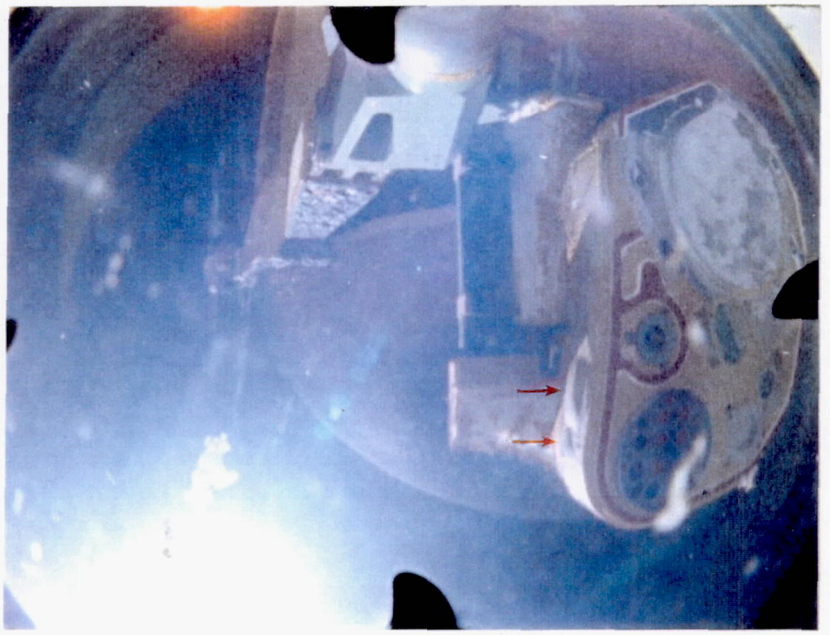


Figure 2.5.1 (B) Blisters on LH2 Umbilical Fire Barrier

Two larger-than-usual areas of blistering were seen on the fire barrier on the outboard side of the LH2 umbilical (5mm lens, frame 5141).

2.5.2 Analysis of Handheld Photography of the ET (Task #3)

DTO-312 handheld photography (Method 4) of the STS-83 ET was acquired after ET separation. A Nikon 35mm camera with a 400mm lens and a 2X extender was used. The OMS-2 attitude pitch maneuver was performed early to assist the crew members in acquiring the ET visually.

Fifteen views of the external tank were acquired (roll 444). The +Z, -Y axis of the ET was imaged. The majority of the ET was in shadow and too dark for analysis. Timing data is present on the hand-held film. The first picture was taken on April 4, 1997 at 19:38:33 UTC (approximately 18 minutes after liftoff), and the last picture was taken at 19:40:54 UTC.

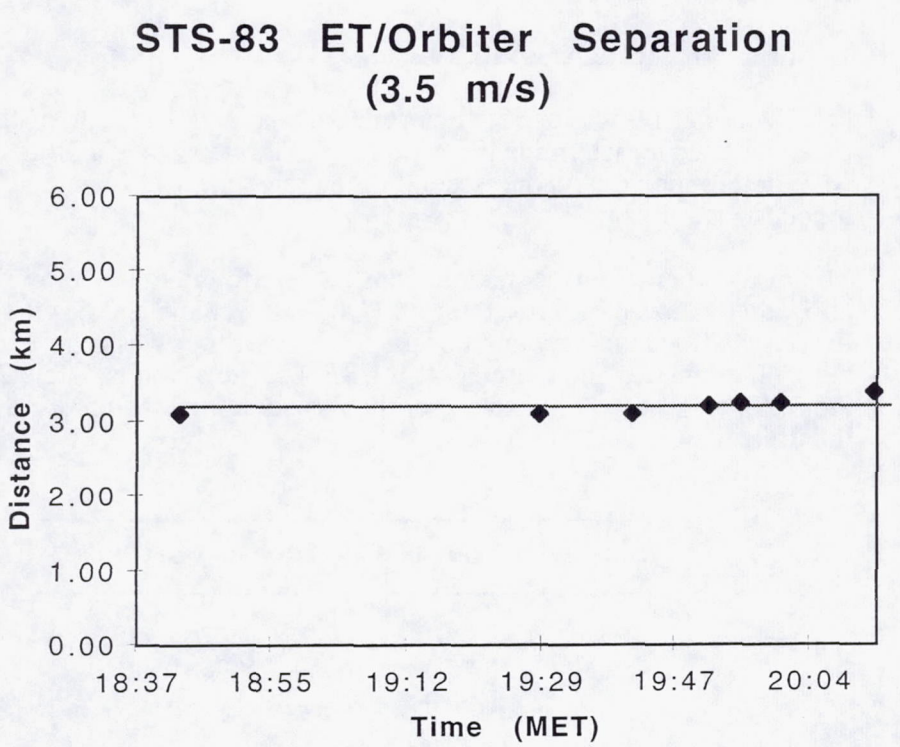


Figure 2.5.2 ET Separation Velocity

The distance of the external tank was calculated on eight frames. On the first usable view, the external tank was calculated to be a distance of 3.1 km away from the Orbiter at 18:43 MET. On the last view, the tank was calculated to be at a distance of 3.4 km (1.5 minutes after the first view). The tank separation average velocity was determined to be 3.5 meters/second (m/s), with an uncertainty of approximately 1 m/s. The tank tumble rate was approximately 0.5 degrees/second and the roll rate was approximately 0.6 degrees/second.

2.6 LANDING EVENTS

2.6.1 Landing Sink Rate Analysis (Task #1)

Film camera EL9 was used to determine the landing sink rate of the main gear and EL1 was used to determine the nose gear sink rate. The sink rates of the Orbiter were determined over a one-second time period prior to main and nose gear touchdown.

The measured main gear sink rate values were found to be below the maximum allowable values of 9.6 ft/sec for a 211,000 lb. vehicle and 6.0 ft/sec for a 240,000 lb. vehicle (the landing weight of the STS-83 Orbiter was reported to be 235,286 lbs.). The sink rate measurements for STS-83 are given in Table 2.6.1. In Figure 2.6.1(A), and 2.6.1(B), the trend of the measured data points for the image data is illustrated.

Sink Rate Prior to Touchdown (1 Second)	
Main Gear	1.5 ft/sec.
Nose Gear	4.0 ft/sec.

Table 2.6.1 Sink Rate Measurements

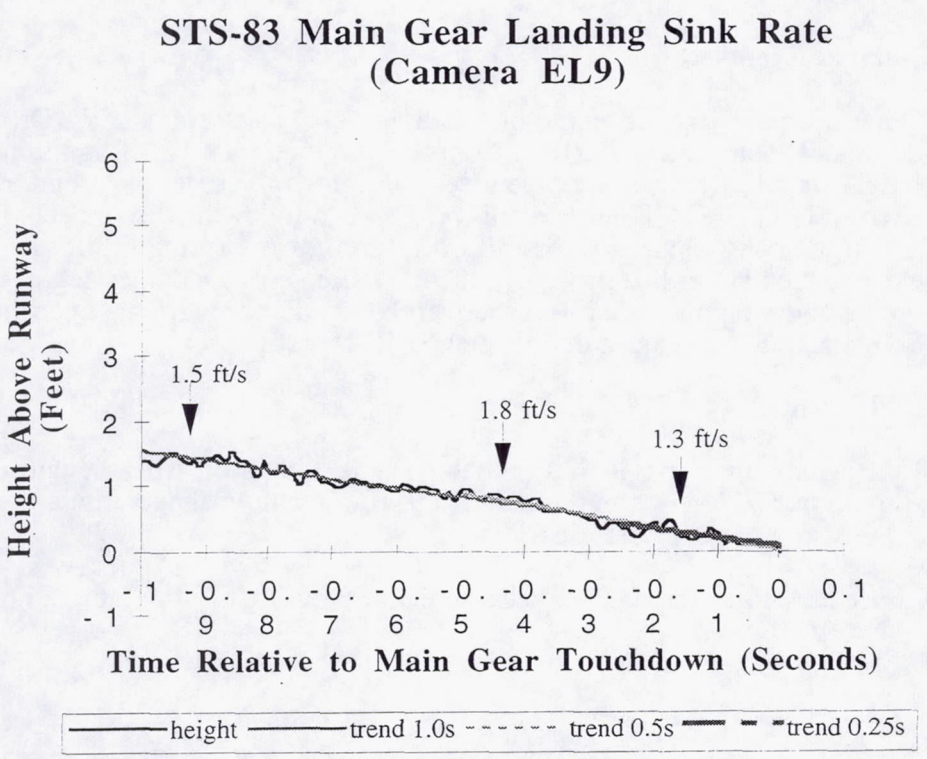


Figure 2.6.1 (A) Main Gear Height versus Time Prior to Touchdown

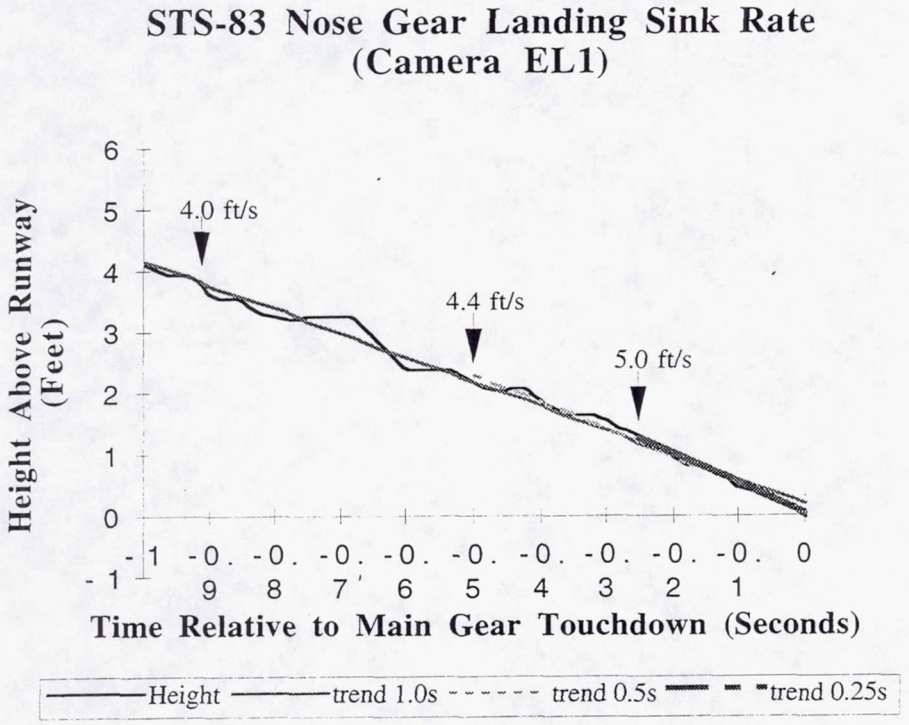


Figure 2.6.1 (B) Nose Gear Height versus Time Prior to Touchdown

2.7 OTHER

2.7.1 Normal Events:

Other normal events observed included: ice and vapor from the ET/Orbiter umbilical areas during SSME ignition, elevon motion at SSME ignition, frost on the ET vent, ET twang, multiple pieces of light-colored debris falling from the LH2 and LO2 TSM T-0 umbilicals prior to and following disconnect, MLP debris at liftoff, acoustic waves during liftoff, birds in view during liftoff, debris in the exhaust cloud after liftoff, vapor off SRB stiffener rings, outgassing of the ET aft dome, body flap motion, roll maneuver, ET aft dome charring, expansion waves, SRB separation, and slag debris after SRB separation.

2.7.2 Pad Events:

Hydrogen ignitor operation, FSS deluge water operation, MLP deluge water activation, GH2 vent arm retraction, TSM T-O umbilical operations, and sound suppression system water operation.

Loose tape-like material was seen on the FSS during liftoff (Camera E54).

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY

National Aeronautics and
Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

Reply to Attn of: EP42 (97-25)

MAY 12 1997

TO: Distribution

FROM: EP42/Thomas J. Rieckhoff

SUBJECT: Engineering Photographic Analysis Report for STS-83

The launch of space shuttle mission STS-83, the twenty-second flight of the Orbiter Columbia occurred on 4/4/97, at approximately 1:20 P.M. Central Standard Time from launch complex 39A (LC-39A), Kennedy Space Center, Florida. Launch time was reported as 97:094:19:20:32.019 Universal Coordinated Time by the Marshall Space Flight Center Flight Evaluation Team. Photographic and video coverage has been evaluated to determine proper operation of the flight hardware.

The photographic coverage of the STS-83 launch was excellent due to the daylight and clear sky conditions. All cameras operated and recorded data except for the Orbiter LO2 umbilical well camera which failed to operate. Camera E11, which views holddown post M-7, provided a blurred image due to film motion during exposure. An automatic exposure control system was used for the mobile launch platform and flight support structure cameras.

Solid Rocket Booster (SRB) holddown post M-7 stud hung up at liftoff. The stud fell down into the catch mechanism once the vehicle had cleared the top of the stud. A dark debris piece of unknown origin was observed at the base of the stud near the top of the shoe during this event.

The following events were observed on this mission and are not considered anomalous. These type events have been observed on previous missions:

a) Loose thermal curtain tape on the right SRB at liftoff near holddown post M-4.
b) The Space Shuttle Main Engine (SSME) mach diamond formation was in the order of 3-1-2.
c) Frost around the eyelid of SSME#2 at liftoff.
d) Paper debris fell aft during early ascent.
e) Debris induced SSME plume streaks during ascent.
f) Condensation collar formation around the vehicle during ascent.
g) Flow recirculation around the external tank (ET) aft dome during ascent.
h) Multiple TPS divots along the ET intertank/LH2 tank scarf joint from the left SRB attach point (-Y axis) to the forward bipod strut (+Z axis).

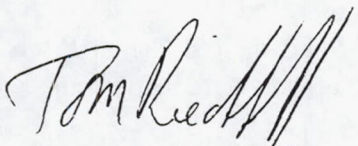
The following event times were acquired:

EVENT	TIME (UTC)	DATA SOURCE
M-1 PIC Firing	19:20:32.028	Camera E9
M-2 PIC Firing	19:20:32.026	Camera E8
M-5 PIC Firing	19:20:32.027	Camera E12
M-6 PIC Firing	19:20:32.028	Camera E13
SRB separation	19:22:35.12	Camera E207

This report and additional information are available on the World Wide Web at URL:

http://photo4.msfc.nasa.gov/STS/sts83/sts83.html.

For further information concerning this report contact Tom Rieckhoff at 205-544-7677 or Jeff Hixson, Boeing North American at 205-971-3082.



Thomas J. Rieckhoff

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13. ABSTRACT *(Maximum 200 words)*

A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-83. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were assessed by the use of computer programs and infrared scanned data during cryogenic loading of the vehicle, followed by on-pad visual inspection. High speed photography of the launch was analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the ice/debris/thermal protection system conditions and integrated photographic analysis of Shuttle mission STS-83 and the resulting effect on the Space Shuttle Program.

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